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EXPERIMENTAL EVALUATION OF VEGETABLE OIL BASED COPPER OXIDE HYBRID NANO FLUID AS A LUBRICANT IN TURNING

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Abstract - *This thesis represents a brief report on synthesis and characterization of CuO nano particles and hybrid nanofluid is produced by mixing of CuO nanoparticles as additive into the mixture of soyabean and castor oil in the ratio 1:1 and nano particles were synthesized by solgel method later these CuO nanoparticles are characterized by X-RD and FESEM with EDX analysis , after confirmation of elemental analysis and nano particles size, copper oxide nano particles Opatsized were dispersed into hybrid base fluid of different concentrations of wt%(0.01wt%, 0.02wt%, 0.03wts%, 0.04wt%, 0.05w%)*

Experimental analysis were carried on these five samples including base fluid such as contact angle is measured by using Goniometer, viscosity studies at different temperature using Redwood Viscometer-II, turning performance were analysed by measuring tool tip temperature, cutting forces in x.y.z direction and surface finish of the final machined work piece were measured by using surface roughness tester

Key Words: **COPPER, OXIDE.HYBRID, HYBRID NANO FLUID, LUBRICANT**

1. INTRODUCTION

Nanofluids are two phase mixtures engineered by dispersing nanometer sized particles with sizes ranging below 100 nm in base fluids (Sarit K. Das et al. 2008). The nanometer sized particles are used for the dispersion in base fluids are nanoparticles, nanofibers, nanotubes and nanorods. Materials generally used as nanoparticles include metal oxides (e.g., silica, alumina, titania, zirconia), oxide ceramics (e.g. Al_2O_3, CuO), chemically stable metals (e.g. copper, gold), carbon in various forms (e.g., diamond, graphite, carbon nanotubes, fullerene) metal carbides (e.g. SiC) and functionalized nanoparticles. The base fluid types include oils, water, organic liquids such as glycols, refrigerants, polymeric solutions, bio fluids, lubricants and other common liquids.

Nanofluids, in which nano-sized particles (less than 100 nanometers) suspended in liquids, have emerged as a potential candidate for the design of heat transfer fluids. The main goal of nanofluids is to achieve highest possible thermal properties at the smallest possible concentrations by uniform dispersion and stable suspension of nanoparticles in host fluids. Nanofluid is defined as colloidal solvent containing dispersed nanometer-sized particles (~1-100 nm). Cooling becomes one of the top technical challenges facing high-tech industries such as microelectronics, transportation and metallurgy and manufacturing. Nanofluids, when are used as coolants can provide dramatic improvements in the thermal properties of host fluids.

The term nanofluid was first coined by Choi where he described the future and hope of this application of nanotechnology. The emergence of nanofluids as a new field of nano scale heat transfer in liquids is related directly to miniaturization trends and nanotechnology. Nanofluids owe its history to the Advanced Fluids Program (AFP) at Argonne National Laboratory (ANL), U.S.A that encompassed a wide range (meters to nanometers) of size regimes and eventually the wide research road became narrow, starting with large scale and descending through micro scale to nano scale, culminating in the invention of nanofluids. New advances in producing nano-sized metallic or nonmetallic particles have allowed producing this new kind of fluid. Mostly the nanofluid thermal conductivities are found to vary non-linearly as a function of nanoparticle loading. Nanofluids due to their excellent properties including better stability and increased thermal conductivity have been investigated by several researchers.

1.1 ADVANTAGES OF NANOFLUIDS

Particle size is the major physical parameter in nanofluids, as it is used to attune the nanofluid thermal properties as well as the suspension stability of nanoparticles. Hence, nanofluids can able to flow freely through mini or micro channels with the dispersion of nanoparticles. The nano suspensions show high thermal conductivity which is mainly due to enhanced convection between the nanoparticles and base liquid surfaces. Another potential benefit is that the nanoparticles have lower dimensions so that the dispersed nanoparticles seems to be like a base fluid molecule in suspension.

The advantages of suspending nanoparticles in base fluids: The surface area and heat capacity of the fluid are increased

The effective thermal conductivity of the fluid is enhanced. The collision and interaction among particles, the surface of flow passage and base fluids are intensified.

Reduction of particle clogging rather than conventional slurries.

The combination of these factors makes nanofluids highly preferable for designing heat transfer fluids.

1.2 PREPARATION METHODS FOR NANOFLUIDS

The initial key step in experimental studies with nanofluids and the optimization of nanofluid thermal properties requires successful preparation methods for producing stable suspensions of nanoparticles in liquids. Some special requirements are essential that means negligible agglomeration of particles, durable, uniform and stable suspension and no chemical change of the fluid, etc. There are two main techniques adopted for the preparation of nanofluids: single-step method and two-step method.

1.2.1 Single step method

Single step method simultaneously produces and disperses nanoparticles directly into the base fluid medium which is suitable for metallic nanofluids. The aggregation problem can be much reduced with direct evaporation condensation method. The inert-gas technique involves the vaporization of source material in a vacuum. In this process of preparation, the condensation forms nanoparticles through direct contact between the base fluid and vapour.

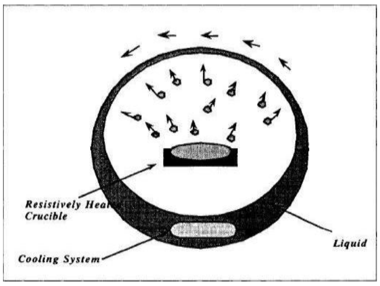

Fig 1.1 Schematic representation of one-step method of nanofluid preparation

The continuous circulation of base fluids minimise the agglomeration of nanoparticles. The schematic representation of direct evaporation condensation technique is shown in figure 1.1. The researchers from Argonne National Laboratory reported another interesting technique is laser ablation technique, in which the metal nanoparticles in deionized water are synthesized by using multi-beam laser ablation in liquids, where the laser parameters controls the size and distribution of nanoparticles.

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1.2.2 Two step method

Two-step method is the most common method for preparation of nanofluids and its schematic representation is shown in figure 1.2. Nanosized solid particles such as nanorods, nanofibers, nanotubes or other functionalized nanomaterials are used in this method. Nanoparticles are initially synthesized in powder form by physical or chemical methods. Then, the nanosized powder particles are dispersed in base fluid in the successive processing step with the aid of intensive ultrasonication method or by using surfactants. This method is most widely used economic method for large scale production of nanofluids, since nanoparticle synthesis techniques were scaled up to industrial production levels.

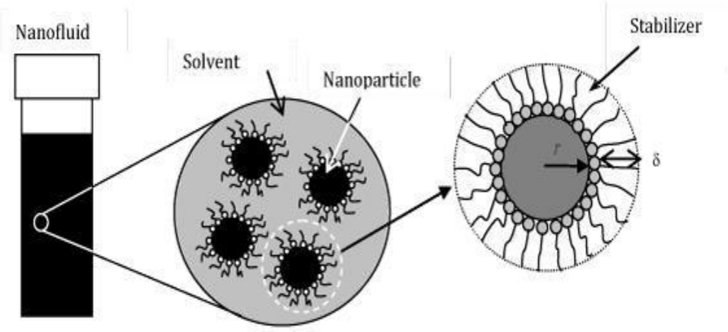


Figure 1.2 Schematic representation of two-step method of nanofluid preparation

when it moves from a high temperature region to low temperature region and gives up this energy through collisions with lower energy molecules. Thermal conductivity of some typical liquids is high. Thermal energy will be conducted in solids by two modes: transport by free electrons and lattice vibration.

1.3 PREPARATION OF NANOFLUID

Nanofluids are new class of fluids powered by dissolving nanometer sized materials such as nanoparticles, nanofibers, nanotubes in base fluid. Nanofluid is used as heat transfer fluid prepared by dispersing nanoparticle in water/ethylene glycol to enhance thermal conductivity and also heat transfer performance. The thermal conductivities of metal nano fluids like Al, Cu, Ag, Mg, and Fe are higher in nature. Thereby, fluids having solid metallic particles are suggestively improved thermal conductivities which will be useful for conventional heat transfer fluids. Normal fluids have low heat transfer properties compared to most metallic fluids.

The improvement of thermal characteristics in heat transfer nanofluid will solve the thermal issue of energy devices. Still researchers are working in synthesis and characterization of nano fluids to find out better thermal property. So nanofluids are suitable to use under flow conditions and the flow of suspension. But these Nano fluids are different from normal heat transfer fluids which have Newtonian characteristics. The rheological properties of nanofluid will ensure the heat transfer property and thermal characteristics. To develop the mechanism of heat transfer enhancement, the fluid-particle and particle- particle interactions within the fluid should have been widely studied. The rheological properties of micro particles under both static and dynamic conditions are completely different from the rheological properties of nanoparticles. The rheological property of nanofluids is studied to understand the mechanism of heat transfer enhancement. In this research, we investigated the optimum thermal conductivity and rheological properties of copper oxide nanofluid dispersed in water/ethylene glycol.

1.4 SELECTION OF NANOPARTICLES:

The thermal conductivity of heating or cooling fluids is a very important property in the development of energy efficient systems. The thermal conductivity of the fluids is one of the basic properties taken into account in designing and controlling the process. Materials used for nanoparticles include chemically stable metals (e.g., Aluminium, Gold, Copper, silver) metal oxides (e.g., Alumina, Copper oxide, silica, Zirconia, Titanium) and carbon in various forms (e.g., Diamond, Graphite, Carbon nanotubes etc.). Prime factors to be considered are ease of availability, costs, thermal conductivity, tendency of the particles to hold them into base fluid with negligible agglomeration etc. Even though metal particles have better thermal conductivity, they have more inclination to agglomerate compared to metal oxides. Present in this work Silica and Tungsten oxide were used.

1.5 BASE FLUID AND NANOPARTICLE MATERIALS:

Numerous and various nanoparticle materials are used for nanofluid preparation. Al_2O_3, TiO_2, CuO, Au, TiC, Ag, SiC, Fe and Cu nanoparticles are generally used in nanofluid study. Carbon nanotubes are also utilized due to their very high thermal conductivity in the longitudinal way. Conventional base fluids typically used in the making of nanofluids are the universal functional fluids of heat transfer applications such as ethylene glycol water and engine oil. To expand the durability of nanoparticles inside the conventional base fluids some additives are added to the combination in small amount.

1.6 Nanoparticle sizes:

Nanoparticles used in nanofluids preparation usually have diameters below 100nm.Particles as small as 10nm, 12nm, 20nm, 25nm, 30nm, 40nm, 50nm, 80nm, 100nm has been used in nanofluids study. The nanoparticles are not spherical but rod or cylindrical shaped the diameter is quit less than 100nm, but length of the nanoparticles might be in order of micrometers, it should also be remembered that due to the clustering fact, particles may form clusters with sizes by the order of micrometers.

Spherical shaped particles are widely used in nanofluids. However, rod shaped, tube shaped and disk-shaped nanoparticles are also used. While, the clusters formed by nanoparticles may fractal like shapes.

1.7 APPLICATIONS OF NANOFLUIDS

Liquid cooling:

Cooling is the major technical challenge facing high tech industries such as microelectronics, metrology, transportation and manufacturing. It is highly desirable for the maintenance of various electronic products at desired operating temperatures for long life time and proper functioning. The cooling performance was significantly enhanced with the aid of nanofluids (Lee and Choi 1996). In the realm of electronics cooling, the industrialists started using nanofluids instead of conventional liquids. In addition, nanofluids could effectively remove hot spots and maintain components at uniform temperatures. Considering the range of efforts to extend liquid cooling technologies and the superior thermal properties, nanofluids would be utilized for hot spot cooling systems for computer, high heat flux, telecom, defence and power electronics uses.

Crystal Silicon Mirror Cooling:

An advanced cooling technology was developed using nanofluids to cool crystal silicon mirrors (Lee and Choi 1996) in high intensity x-ray sources was one among the initial applications in the field of nanofluid research. Lee and Choi performed analysis for the estimation of better performance of microchannel heat exchangers with liquid nitrogen, conventional water and finally nanofluids as working fluids. Their research efforts showed that nanofluids could significantly increase power densities and reduce thermal resistances. Furthermore, the chance of flow-induced vibration and thermal distortion were much eliminated by passing nanofluids through microchannels within the silicon mirror. The researchers also investigated that power densities of around 3000
W/cm2 for high aspect ratio microchannels were accomplished with nanofluids.

Electronics Cooling

Ice Dragon cooling nanofluid coolant -32oz is the most advanced cooling liquid available for electronic applications and is capable of improving heat transfer rates as much as 20%. Upon certain limitations on practical heat exchanger designs, this cooling fluid was produced for the electronics field by allowing increased heat removal with the smaller sized cooling hardware. This cooling fluid was exclusively designed for liquid cooled computer systems capable of allowing more thermal head room and pushing the thermal envelope of performance than any other cooling fluid. Solvent-free ionic molybdenum disulphide (MoS_2)

nanofluids were synthesized by functionalizing nanoscale MoS2 from hydrothermal synthesis with an ionic oligomeric canopy and charged corona. These synthesized nanofluids were homogeneous amber-like fluids with Newtonian flow feature. They are inevitable candidates for the lubrication of nano and micro electro mechanical systems.

Vehicle Cooling

Nanoparticles could not only be dispersed in engine oils and coolants, but also in gear oils, lubricants, transmission fluids and other fluids as well. These nanofluids provide better insight into thermal management system and better lubrication. Tzeng et al. (2005) were the pioneers by using nanofluid technology in automatic power transmission system. In their research work, Al2O3 and CuO nanoparticles were dispersed in transmission oil to investigate the optimum possible compositions of nanofluid for enhanced heat transfer performance. The temperature distribution of the RBC exterior were measured at four varying rotating speeds (400, 800, 1200, and 1600 rpm) and the conditions of real car at various rotating speeds were simulated. The investigations revealed that better heat transfer effect was achieved with CuO nanofluids and they have the efficiency of lowest temperature distribution at both low and high rotating speeds. This work is vital since it shows real world application of nanofluids representing a greater step forward for industrial applications of nanofluids.

Transformer Cooling

The power generation industry is greatly interested in transformer cooling application with the usage of nanofluids for reducing size and weight of the transformer. The ever-increasing demand for greater electricity production, especially in our nation will require upgrades of most transformers at some point in the near future at a potential cost of millions of dollars in hardware retrofits. Yu et al. (2007) and Xuan and Li (2000) examined that the heat transfer properties of transformer oils could be significantly improved by using additives of nanoparticles. Specifically, nanofluid based transformer oil is likely to be the next-generation cooling fluid in transformers.

Space and Nuclear Systems Cooling

Vassallo et al. (2004) and You et al. (2003) explained the unprecedented phenomenon that nanofluids could able to increase the critical heat flux (CHF) by triple fold measure in pool boiling. Kim et al. (2006) found that the high surface wettability produced by nanoparticle addition could demonstrate remarkable thermal properties of nanofluids. Experimental investigation is required in developing realistic predictive models of CHF in nanofluids. The upper heat flux limit in nucleate boiling systems and the ability to increase the CHF, is of paramount practical importance to ultrahigh heat flux devices that use nucleate boiling, such as nuclear reactor components and high-power lasers. Hence, nanofluids have raised up exciting possibilities for simplifying cooling requirements for space applications and increasing chip power in electronic devices. The Massachusetts Institute of Technology (MIT), United States has established an interdisciplinary centre for nanofluid technology for the nuclear energy industry. The researchers were evaluating the vital impact of the use of nanofluids on the safety, economic and neutronic performance of nuclear systems.

Defence Applications

Numerous military systems and devices, such as military vehicle components radars, high powered military electronics, lasers, require high heat flux cooling to the level more than 1000 W/cm2. Cooling with conventional heat transfer fluids at this high level is much difficult. Nanofluid technology also provides advanced cooling systems for military combat vehicles, high-power laser diodes and submarines. It seems that nanofluid research in defense applications considers energy harvesting through chemical reactions or multifunctional nanofluids with added thermal energy storage.

Tribological Applications.

Nanofluid technology was applied in developing better lubricants and oils. Li et al. (2004) reported performance on lubricant nanofluids containing ZrO2 and IrO2 nanoparticles. The experimental results showed that nanoparticles decrease friction on the surface of 100 C6 steel. Que et al. (1997) reported that surface modified nanoparticles stably dispersed in mineral oils are very effective in enhancing load-carrying capacity and reducing wear in lubrication application.

Biomedical Application

Nanofluids were also developed for medical treatments, including cancer therapy. Iron-based nanofluids could be used to produce higher temperatures around the tumor cells, by killing cancerous cells without affecting the nearby healthy tissues (Jordan et al. 1999). Nanofluids could also be used for safer surgery by cooling around the surgical region, thereby enhancing a patient's chance of survival and reducing the risk of organ damage.

Recent applications

Nanofluids in CPU cooler
The Reserator 3 Max nanofluid cooler was developed by Zalman's company with the features of nanofluidic technology and created the first commercial CPU cooler

1.8 INTRODUCTION TO MACHINING

Machining

Machining is one of the essential and challenging tasks in the manufacturing industries which involve a controlled removal of material from the substrate by using a cutting tool. As machining involve plastic deformation of workpiece material and also friction between tool- chip and tool-workpiece interface these both phenomena needed high amount of energy which further converted into heat. While machining low strength alloys there is less amount of heat generation take place but machining of ferrous and other high strength alloys is associated with larger amount of heat generation. The dissipation of this generated heat is one of the important factors as per good machining requirements. If the generated heat is not dissipated effectively, may cause for reduced tool life, poor surface finish of machined face and thereby reduction in overall performance of the machining process obtained as a result. Although high speed machining is desirable condition in most of the cases, the penalty of higher heat generation needs to be minimized.

Therefore, there is a need to control friction between the tool-chip and tool-work, and reduce the heat generated. For this purpose, a bulk amount of cutting fluid is forced to spray on-to the cutting zone. The cutting fluid cools the cutting zone and provides lubrication for tool–chip and tool-work contact, thereby reducing the friction and also the temperature generated. This provides less tool wear, a good surface, and less cutting forces during machining. Even with all of these benefits, there are also negative impacts of cutting fluids such as carrying problems, disposal problems, the toxic nature of fluid, and also the environmental pollution such as water pollution, soil pollution, and air pollution This need gave birth to many alternative techniques to minimize the quantity of cutting fluid used .Some such techniques which came forward were:

Dry machining
Use of coated tool
Wet machining

Dry machining

This is an environmental concern call for the elimination of the cutting fluid in metal cutting operation. In the recent past, a lot of interest is being taken in the machining without using cutting fluid. When no cutting fluid is used during machining, it is called dry machining. Dry machining associated with low cutting speeds and easily machinable materials. Usually, dry machining is not appropriate in cases where great surface finish and high precision in dimensional stability are required. This is so because dry machining involves high temperature generation which enhances the chances of formation of built up layer. This built up layer due to its unsteady nature breaks and takes away a portion of tool material due to its high adhesive nature causing tool wear. The broken segments when stick to the machined surface deteriorates the surface finish. Thus, dry machining without any lubricating and cooling enhancement is not preferred in general cases of machining.

Use of coated tool

It has been well established that advanced surface coatings on cutting tools improve wear resistance by modifying the contact conditions between the chip and tool interface. As a result of the recent developments in cutting tool industry, coated tools have made a major contribution to the metal cutting operations in terms of machining quality, tool life and cutting time. The confront of modern machining industries is aimed mainly on the getting of high quality, surface finish, in terms of work piece dimensional accuracy, high production rate and less wear on the cutting tools. So as to avoid the usage of cutting fluids during machining processes, nowadays coated tools are gaining fame. In this method the tool inserts are provided with a coating which can serve the following purposes.

It should have low thermal conductivity so that it does not allow any heat to enter into the bulk material of the tool.
It should have good resistance to abrasion wear and must possess high thermal and chemical stability.

It must possess low friction coefficient and must be securely bonded to the tool substrate material.

Most regularly used coating materials are titanium-based coating such as TiAlN, TiN, TiAlCrN etc.

Wet machining

Properties of cutting fluid

Cutting fluid also known as lubricants and coolants as it fulfills both the desired purpose. It serves the cooling effect to minimize the negative thermal affects and lubricating effect to provide better surface finish. Cutting fluids are used extensively in machining operation to:

Cool the cutting zone, thus reducing workpiece temperature and distortion, and improving tool life.
Reduce friction and wear, hence improving tool life and surface finish.
Reduce forces and energy consumptions.
Wash away chips.
Protect the newly machined surfaces from environmental attack.
The following are the essential properties, which cutting fluids must possess in order to fulfill their desired function:
A good cutting fluid is defined with its large specific heat capacity and high thermal conductivity.
It should have low viscosity in order to easily enter through small gaps.
It should be non-corrosive, non-toxic and should not react with workpiece and tool material.
It should be ease as per availability and should not be much expensive.
It should have high flash point to maintain its properties.
It should be chemically and physically stable.

Types of cutting fluid

Cutting fluids can be classified in to two following broad categories:
Water miscible cutting fluids
Mineral oil base cutting fluids
Cryogenic cutting fluid

Water miscible cutting fluids
In water miscible cutting fluids, water stands as a main base fluid. Water is well known for its excellent cooling property. Thus, water miscible cutting fluids have good heat absorbing capacity. Water miscible cutting fluids are a mixture of water-soluble oil and water. Generally, emulsifiers (soap like substance) used as a water-soluble oil, when it gets mixed with water in a small quantity a milky kind of fluid produces, which used to supply in cutting zone area.

Mineral oil-based cutting fluids
These oils are mixture of several mineral oils or vegetable oils with no concentration of water. Some additives compounds such as phosphorous, sulphur, chlorine based can be added to base fluid in order to enhance their cooling and lubricating properties.

Cryogenic cutting fluid
Cryogenics is defined as the study of the production and behavior of materials at very low temperatures (below −150 °C, or 123 K). Mostly liquid nitrogen is used as the cryogen material. The use of liquid nitrogen as a cryogenic coolant in metal cutting has received renewed recent attention because liquid nitrogen is a safe, clean, colorless and non-toxic coolant that requires no expensive disposal and can significantly improve tool life. It constitutes about four-fifth of the atmospheric gases. Its boiling point is -198.79ºC and melting point is -210.01ºC. During machining, the cryogenic coolant is supplied to the machining area (maximum heat zone area). The coolant takes heat by convection and drops down the maximum temperature reached thus contributing in tool life enhancement.

Conventional flood cooling
Conventional flood cooling is a traditional technique of cooling and lubrication of cutting zone. Under normal flood cooling flow rate typically ranges from 10 l/min (0.01 m3/min) for single-point cutting tools to 225 l/min (0.225 m3/min) per cutter for multiple-tooth cutters, such as in milling. In operations such as drilling and end milling, fluid pressures in the range of 700-14000 kPa are used to wash away the chips. Despite all of these benefits, there are also negative impacts of cutting fluids such as:
Disposal of cutting fluid
Cost of cutting fluid
Spreading of cutting fluid around the machine
Harmful residuals
Disposal of wet chips
Less visibility

1.10 NANOLUBRICATION

On account of emerging 'nanotechnology' the concept of nanofluid lubrication has been developed. Nano lubrication is a process of effective cooling and lubrication of cutting zone during any machining process by involving nanofluid instated of normally used cutting fluids.

CHAPTER 2

2. LITERATURE REVIEW

The concept of nano fluid is given by choi in 1995 as an engineered colloid made of base fluid and nano meter sized solid particles (1-100nm diameter, volume fraction typically 5%. Compared to traditional fluids or suspensions containing coarse particles, nanofluids are expected to have superior thermal and tribological properties.

The main reason of the improvement in the properties of such fluids may be listed as:

The suspended nanoparticles increase the thermal conductivity of fluid.
The suspended nanoparticles increase the specific surface area and therefore increases in heat transfer between the particles and fluids.

Properties such as thermal conductivity, specific heat capacity, and viscosity can be adjusted by changing the particle concentration to suit different applications.

Suspended nanoparticles in a conventional fluid increase in tribological properties such as friction, wear and extreme pressure property.

By nature of application base fluid and nano particles were used, current nanoparticles used in creating nanofluids include aluminium oxide (Al_2O_3) copper (Cu), copper oxide (CuO), gold (Au), silver (Ag), iron (Fe), titanium oxide (TiO_2) and silicon carbide (SiC). The base fluid commonly used to create nanofluids include water, oil, ethylene glycol, acetone and decene. The thermal conductivity of the solid nanoparticles is higher than base fluid. A survey of literature has been conducted on vegetable oil based nanofluids used in machining process and is presented as below.

Haddad et al. (2014) have studied about the nano-fluids preparation methods. Although many preparation methods were proposed, it is still a challenge to make a nanofluid homogeneous and long-term stable with negligible agglomeration, and without affecting the thermo-physical properties. Three methods have been used to prepare nanofluids: 1) Sonication. 2)pH control. 3) Surfactants

Trajano et al. (2014) Has investigated the oxide nanoparticles as additives for vegetable lubricants and added oxide nanoparticles (ZnO and CuO) in order to improve abrasion resistance and friction in sunflower oil and soyabean oil , The epoxidized sunflower and soybean oils have properties suitable for the formulation of lubricants, especially for applications operating over a wide temperature range, because of its excellent viscosity index. These bio-lubricants showed good performance in boundary conditions, decreasing friction coefficient and improving film formation on metal surface. The nanoparticle deposition on surface is hampered and they act as a third body increasing the wear.

Jatti et al. (2015) investigated Copper oxide nano-particles as friction-reduction and anti-wear additives in lubricating oil, performed all tests were performed under varying loads and concentrations of nanoparticles in lubricating oil. The friction and wear experiments were performed using pin on disc tribotester. The results demonstrated that nanoparticle additives can effectively improve the engine oil lubricating properties. This is because nanoparticles enter the friction zone along with the flow of lubricant, nano-particle concentration of 0.5 wt%, 1 wt%, & 1.5 wt% were tested nano-lubricants exhibited reductions in friction and wear.

Wang et al. (2018) has examined processing characteristics of vegetable oil-based nanofluid MQL for grinding different workpiece materials the processing characteristics of three MQL lubricants for three workpiece materials were evaluated. The optimal combination of MQL lubricant type and workpiece material for machining was determined to obtain the minimum force ratio, specific grinding energy, and surface roughness, and the maximum G ratio, this oil film exhibits poor anti-friction and anti-wear performance and presents instability in harsh grinding environment. strength and hardness.

Li et al. (2011) about Preparation and properties of copper-oil-based nanofluids this study, the lipophilic Cu nanoparticles were synthesized by surface modification method to improve their dispersion stability in hydrophobic organic media. The oil-based nanofluids were prepared with the lipophilic Cu nanoparticles. The transport properties, viscosity, and thermal conductivity of the nanofluids have been measured. The viscosities and thermal conductivities of the nanofluids with the surface-modified nanoparticles have higher values than the base fluids do.

Gupta et al. (2019) examined on performance evaluation of vegetable oil-based Nano-cutting fluids in environmentally friendly machining of Inconel-800 alloy the application of nano-cutting fluids has gained much attention in the machining of nickel-based super alloys due their good lubricating/cooling properties including thermal conductivity, viscosity, and tribological characteristics. It is worth mentioning that the presence of small quantities of graphite in vegetable oil significantly improves the machining characteristics of Inconel-800 alloy as compared with the two other nanofluids.

Chatha et al. (2016) studied on objective. Minimal quantity of lubrication (MQL) is a recent technique introduced in machining to obtain safe, environmental and economic benefits, reducing the use of coolant lubricant fluids in metal cutting. The objective of this work is to compare the performance of different lubrication conditions (dry, flooded, pure MQL and nanofluid MQL) with respect to the cutting forces (thrust force and torque), tool wear and surface roughness in the drilling of aluminum 6063 alloy by using HSS drill tools. In addition, the nanofluid MQL effectively eliminates chips and burrs to enhance the surface quality of holes and also increases the tool life by obtained lowest tool wear.

Das et al. (2019) studied about Performance comparison of vegetable oil based nanofluids towards machinability improvement in hard turning. Cutting are investigated and analyzed through this article during hard turning using minimum quantity lubrication (MQL). Cutting force, tool wear (flank and crater), surface integrity (surface roughness, residual stress, microhardness, and surface morphology), and chip morphology are considered as technological performance characteristics to evaluate the machinability of hardened AISI 4340 steel. Additionally, the effect of various fluid properties like thermal conductivity, viscosity, surface tension and contact angle were examined for all nanofluids. Singh et tal (2017) investigated on alumina-graphene hybrid nano-cutting fluid in hard turning, in this investigation by mixing alumina-based nanofluid with graphene nanoplatelets (GnP) in the volumetric concentrations of 0.25, 0.75 and 1.25 vol. %. It was noted that an increase of nanoparticle concentration enhances both, the thermal conductivity and viscosity, though the hybrid nanofluid has lower thermal conductivity compare to its constituents and the viscosity lies in between its constituents. Hybrid nanofluid shows better wettability results as compared to alumina-based nanofluid as well as base fluid.

Sharma et al. (2017) investigates the effect of hybridization of two different nanofluids (alumina and molybdenum disulphide) in turning of AISI 304 stainless steel. The hybrid nanofluid was prepared by mixing alumina-based nanofluid with molybdenum disulphide (MoS2) nanoparticles in a fixed volumetric proportion of 90:10. The prepared base fluid (Alumina nanofluid) and hybrid nanofluid in various nanoparticle concentrations of 0.25, 0.75 and 1.25 vol.% have been tested for their thermophysical properties at different temperatures. Furthermore, pin on disc test, and contact angle measurement of all the nanofluid samples was conducted to examine their tribology and wettability, respectively. The machining performances of hybrid nano-cutting fluid are compared with that of alumina-based nanofluid in terms of machining forces and surface roughness.

Khandekar et al. (2014) works on the nano-cutting fluid for enhancement of metal cutting performance nano-cutting fluids are the mixtures of conventional cutting fluid and nanoparticles. Addition of the nanoparticles can alter wettability, lubricating properties, and convective heat transfer coefficient (cooling properties) of nano-cutting fluids. In the present work, nano-cutting fluid is made by adding 1% Al2O3 nanoparticles to conventional cutting fluid, and chip thickness are reduced by the using nano-cutting fluid compared to dry machining and machining with conventional cutting fluid.

Ganesan et al. (2018) found that, on Experimental investigation of copper nanofluid based minimum quantity lubrication in turning of H 11 steel is the results reveal that copper nanofluids with MQL provide a substitute for dry and oil machining. Response surface methodology has been used to derive optimal values and mathematical models. The surface roughness and tool wear were decreased under optimal machining conditions. Generation of large notched tooth in chips has been minimized with copper nano fluids.

Noori1 et al. (2019) studied the influence of adding CuO and MoS2 Nano-particles to Castor Oil and molding Oil on tribological Properties, (MoS2) nanoparticles powder in both organic (castor oil) and mineral oil (molding oil) were investigated. These properties include coefficient of friction and wear between two surfaces, CK50 steel alloy and 2024-T4 aluminum alloy. The Nano lubricants were prepared by dispersing CuO and MoS2 variable weight fractions 0.3, 0.5, 0.7, 1.0 and 2.0% in each oil lubricant. how Nano-lubricant additives could contribute towards tribological enhancement and improved product quality.

Padmini et al. (2013) studied that on performance of nano solid lubricant suspensions in vegetable oils in turning of AISI1040 steel in minimum quantity lubrication (MQL). Soybean, canola and coconut oils are taken as base lubricants with suspensions of 100nm sized boric acid particles, average tool flank wear and surface roughness of the machined surface with cutting speed and feed are studied with the prepared nano lubricants. Results are encouraging and coconut oil seems to be more advantageous compared to other vegetable oils.

Guo et al. (2016) experimentally found that Vegetable oil is employed as base fluid in precision grinding because of its biodegradability and non- pollutant properties. Castor oil exhibits superior lubrication performance to other vegetable oils, but its high viscosity and poor flow limit its application in industrial production. In this study, castor oil was used as base oil and individually mixed with six other kinds of vegetable oils (i.e., soybean, maize, peanut, sunflower, palm, and rapeseed oils) at a ratio of 1:1 to change the rheological properties of the former. Each mixture was obtained as base oil for minimum quantity lubrication grinding. The amplitude of the surface profile curve in coefficient is higher (0.51) than those under other mixed oils; hence, the workpiece showed the optimal surface quality.

Rashin, et al. (2013) found that coconut oil-based copper oxide nanofluids of various concentrations have been prepared by ultrasonically assisted two step method. Viscosity studies have been made experimentally and theoretically at various temperatures and shear rates for different concentrations of nanofluid ranging from 0% to 2.5%. The measured viscosities of nanofluids are compared with existing theoretical models and found to have very slight deviation due to size, morphology and interactions. New empirical correlations are proposed for predicting viscosity of CuO coconut oil nanofluid at various temperatures and concentrations.

Kole et al. (2011) investigated on effect of aggregation on the viscosity of copper oxide gear oil nanofluids, that results on viscosity of the stable nanofluids, prepared by dispersing 40 nm diameter spherical CuO nanoparticles in gear oil are presented. Viscosity of the studied nanofluids displays strong dependence both on CuO loading in the base fluid, as well as, on temperature between 10 and 80 C. Temperature variation of the nanofluid viscosity agrees very well with the modified Andrade equation, reported by Chen et al.

Eltaggaz1 et al. (2018) used austempered ductile iron (ADI) is rapidly increasing in many engineering applications such as automotive. However, other properties such as low thermal conductivity undesirably affects ADI machinability and accelerate cutting tool failure. Additionally, other issues associated with cutting ADI are the high cutting temperature, high pressure and dynamic loads, and tendency of chip to adhere to cutting tool face. Minimum quantity lubrication (MQL) serves as the best alternative to flood cooling from an environmental perspective as it minimizes the amount of cutting fluid; however, its heat capacity is lower than the traditional flood coolant.

Aparna et al. (2012) have prepared by novel sol-gel method. In this technique CuCl2.6H2O is added with acetic acid and heated to 100 C with continuous stirring. To control the pH of the above solution, NaOH is added to the solution till pH reached desired value. The color of the solution changed from blue to black with precipitation. The black precipitation was washed 3-4 times with distilled water. Finally, the solution was centrifuged and dried in air for one day

Chand et al. (2011) CuO nanoparticles have been synthesized by sol-gel method and sintered in air at various selected temperatures ranging from 100 to 400 0C. The high purity copper nitrate (Cu (NO3)2) and sodium hydroxide (NaOH) are dissolved in distilled water and sodium hydroxide solution is added drop wise with constant stirring to maintaining the PH~14. The chemical reaction between copper nitrate and sodium hydroxide solutions occurs as follows and forms the Cu (OH)2 gel. The resulting Cu(OH)2 gel is washed several times with distilled water until free of nitrate ions, then finally dried by heating at 70 0C for 5 hours.

Kankanit et al. (2013) has synthesized CuO nanoparticles were synthesized by precipitation method using different precursors as copper nitrate (Cu(NO3)2) and copper chloride (CuCl2) and copper nitrate (Cu(NO3)2.3H2O). First, each precursor was dissolved in 100 ml deionized water to form 0.1 M concentration. NaOH solution (0.1 M) was slowly dropped under vigorous stirring until pH reached to 14. Black precipitates were obtained and repeatedly washed by de-ionized water and absolute ethanol for several times till pH reached 7.

From literature survey, it was found that vegetable oils are bio-degradable and non-toxic, vegetable oil based nanofluid and hybrid nanofluid is used in different cutting and machining process. Many research scholars worked on various vegetable and hybrid nano fluids, such as palm oil, soybean oil, castor oil, sesame oil and canola oil. In this investigation hybrid nano fluid prepared by using castor and soybean oils with dispersion of CuO nano particles

CHAPTER 3

3. METHODOLOGY

3.1 INTRODUCTION

In these present experimental studies, nanofluids are prepared in a two-step process. The main advantage of this two-step preparation method is that it produces nanoparticles under clean conditions, without undesirable surface coatings and other contaminants. The fabrication of nanomaterials with well-defined structures and precisely controlled sizes is crucial to the development of nanotechnology. Therefore, rapid research developments have been made in the field of metal oxide nanostructures in terms of their growth and applications. In this chapter, the information about the preparation of copper oxide and hybrid base fluid is taken which means mixture of two or more fluids i.e. castor oil and soybean oil and studied about viscosity at different temperatures

3.2 MATERIALS USED FOR PREPARING NANOPOWDER

Copper chloride (CuCl2)
Sodium Hydroxide (NaoH) Pellets
Distilled water
Glacial acetic acid
Hydrochloric acid (HCl)
Acetone
Ultrasonic cleaner
Magnetic stirrer
Muffle furnace
Planetary ball mill

3.2.1 Synthesis of Copper Oxide Nano powder

Copper oxide with chemical formula CuO is prepared by sol gel method

In this method, copper chloride is used as a precursor and sodium hydroxide as stabilizing agent.

For synthesis chemicals such as copper chloride, sodium hydroxide and hydro chloric acid were purchased from Sigma Aldrich chemicals they are in analytic grade

CuO nanopowders were prepared by sol-gel method. The aqueous solution of CuCl2.6H2O (0.2 M) was pre-pared in cleaned round bottom flask.

1 ml of glacial acetic acid was added to above aqueous solution and heated

to 100 C with continuous stirring.

8 M NaOH is added to above heated solution till pH reached to 7.

CuCl2 +2NaoH → CuO+NaCl+H20

The color of the solution turned from blue to black Immediately and the large amount of black precipitate is formed in the bottom of the flask.

The precipitate was centrifuged and washed 3-4 times with deionized water.

The obtained precipitate was dried in air for 24 h.

This CuO powder was used for the characterization of the material.

Synthesis of Cuo

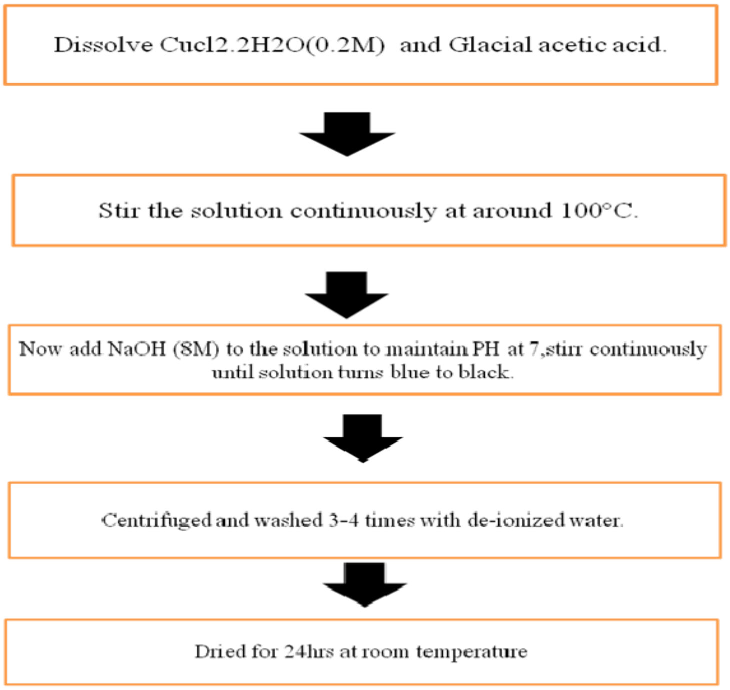


Fig 3.1 Synthesis of Cuo nanoparticles

Ultra-sonic cleaner

Low-intensity or high-frequency ultrasound is mainly used for analysis, non-destructive testing and imaging. High-intensity ultrasound is used for the processing of liquids such as mixing, emulsifying, dispersing and de agglomeration, or milling. When sonicating liquids at high intensities, the sound waves that propagate into the liquid media result in alternating high-pressure (compression) and low-pressure (rarefaction) cycles, with rates depending on the frequency. During the low-pressure cycle, high-intensity ultrasonic waves create small vacuum bubbles or voids in the liquid. When the bubbles attain a volume at which they can no longer absorb energy, they collapse violently during a high-pressure cycle. This phenomenon is termed cavitation. Cavitation, that is "the formation, growth, and implosive collapse of bubbles in a liquid. Cavitational collapse produces intense local heating (~5000 K), high pressures (~1000 atm), and enormous heating and cooling rates (>109 K/sec)" and liquid jet streams (~400 km/h)" Cavitation can be produced in different ways

By high-pressure nozzles, rotor-stator mixers, or ultrasonic processors. In all those systems the input energy is transformed into friction, turbulences, waves and cavitation. The fraction of the input energy that is transformed into cavitation depends on several factors describing the movement of the cavitation generating equipment in the liquid. The intensity of acceleration is one of the most important factors influencing the efficient transformation of energy into cavitation. Higher acceleration creates higher-pressure differences.

This in turn increases the probability of the creation of vacuum bubbles instead of the creation of waves propagating through the liquid. Thus, the higher the acceleration the higher is the fraction of the energy that is transformed into cavitation. In case of an ultrasonic transducer, the amplitude of oscillation describes the intensity of acceleration. Higher amplitudes result in a more effective creation of cavitation. In addition to the intensity, the liquid should be accelerated in a way to create minimal losses in terms of turbulences, friction and wave generation. For this, the optimal way is a unilateral direction of movement.

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. Magnetic stirrers are often used in chemistry and biology, where 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. The limited size of the bar means that magnetic stirrers can only be used for relatively small experiments, of 4 liters or less. Stir bars also have difficulty in dealing with viscous liquids or thick suspensions. For larger volumes or more viscous liquids, some sort of mechanical stirring is typically needed.

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.

Fig 3.2 CuCl2 solution on Magnetic stirrer

Fig3.3 Adding 8M NaoH solution dropwise

3.4 Color is changing bluis Green to black precipitate

Fig 3.5 Filtration process

Fig 3.6 Hand grinding process

3.3 CASTOR OIL:

Castor oil is a vegetable oil pressed from castor beans. The name probably comes from its use as a replacement for castoreum.

Castor oil is a colorless to very pale-yellow liquid with a distinct taste and odor. Its boiling point is 313 °C (595 °F) and its density is 961 kg/m3. It is a triglyceride in which approximately 90 percent of fatty acid chains are ricinoleates. Oleate and linoleates are the other significant components.

Castor oil and its derivatives are used in the manufacturing of soaps, lubricants, hydraulic and brake fluids.
Density= 0.950 gm/ml

3.4 SOYABEAN OIL

Soybean oil is a vegetable oil extracted from the seeds of the soybean (Glycine max). It is one of the most widely consumed cooking oils. As a drying oil, processed soybean oil is also used as a base for printing inks (soy ink) and oil paints.

Soybean oil is one of many drying oils, which means that it will slowly harden (due to free-radical based polymerization) upon exposure to air, forming a flexible, transparent, and waterproof solid.
Density = 0.925gm/ml

3.5 SYNTHESIS OF CuO HYBRID NANOFLUID

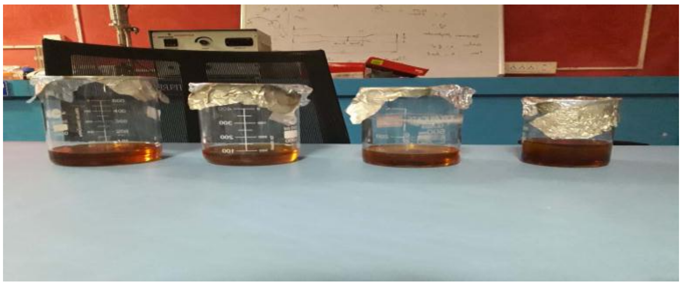
Base oil Castor oil and soybean oil in the ratio 1:1
0.01 wt% Cuo Nanopowder
0.02 wt% Cuo Nanopowder
0.03 wt% Cuo Nanopowder
0.04 wt% Cuo Nanopowder
0.05 wt% Cuo Nanopowder

Table 3.1 Different concentrations of CuO and oils

Weight percentage	CuO in grams	Castor oil soybean oil (1:1 ratio)
0.01%	0.00935	50ml+50ml
0.02%	0.01803	50ml+50ml
0.03%	0.02811	50ml+50ml
0.04%	0.0468	50ml+50ml

One of the most important factors of the nanofluid properties is the rate of dispersion and stability of nano particles inside the base fluid. When dispersion of particles inside the base fluid is not good, it is possible that agglomeration and precipitation of nanoparticles occur, in this case, macro particles, like emulsions, develop which cause damage to frictional surfaces and also obstruct the lubricant vents.

In the present research, to disperse nanoparticles inside the base oil, we used three mechanical methods including bath and probe ultrasonic methods. To achieve the best and the most stable, a 0.01 wt.% sample oil/CuO has been made using each of the two mentioned methods. All of the samples were maintained inside the completely transparent glassy containers in a completely stagnant condition for about 720 hours for the purpose of evaluating their stability conditions. In this period of time, the stability condition of all the samples were periodically and visually inspected and recorded.



3.7 Hybrid nanofluids with different concentrations of CuO

Hybrid nano fluids

Nanoparticles in each of the two samples had precipitated a considerably amount although the rate of precipitation in the sample which was made by the probe sonication was very less than one sample. It seems that sue to high viscosity of base oil and also the agglomerated state of nanoparticles, for opening and dispersing nanoparticles inside the base oil, we need a great amount of energy to supply in the ball method at a greater rate with respect to ultrasonic method

The nanofluid is prepared first 0.01 wt.% CuO is taken in 1:1 ratio i.e. 50 ml castor oil with 50ml soybean oil which is stirred for one hour, similarly 0.02,0.03,0.04 and 0.05 wt.% CuO is taken in 100ml of hybrid nanofluid is stirred along with hybrid oil as shown in figures. We got the hybrid nanofluid and need to inspect stability and dispersion by observing day by day visually.

3.8 Visual inspection day by day (day1)

3.9 Particles settled down (day11) by visual inspection

3.6 FIELD EMISSION SCANNING ELECTRON MICROSCOPY (FE-SEM) & ELECTRON DISPERSION X-RAY SPECTROSCOPY (EDX OR EDS)

Nanotechnology has strongly driven the development of recent electron microscopy, with demands not only for increasing resolution but also for more information from the sample. The field emission scanning electron microscope (FE-SEM) images a sample surface by raster scanning over it with a high-energy beam of electrons. The electrons interact with the atoms comprising the sample to produce signals that contain information about surface topography, composition and other properties, such as electrical conductivity. The function of the electron gun is to provide a large and stable current in a small beam. There are two classes of emission source: thermionic emitter and field emitter. Emitter type is the main difference between the Scanning Electron Microscope (SEM) and the Field Emission Scanning Electron Microscope (FE-SEM).

Thermionic Emitters use electrical current to heat up a filament; the two most common materials used for filaments are Tungsten (W) and Lanthanum hexa boride (LaB6). When the heat is enough to overcome the work function of the filament material, the electrons can escape from the material. Thermionic sources have relative low brightness, evaporation of cathode material and thermal drift during operation. Field Emission is one way of generating electrons that avoids these problems. A Field Emission Source (FES); also called a cold cathode field emitter, does not heat the filament. The emission is reached by placing the filament in a huge electrical potential gradient. The FES is usually a wire of Tungsten (W) fashioned into a sharp point. The significance of the small tip radius (~ 100 nm) is that an electric field can be concentrated to an extreme level, becoming so big that the work function of the material is lowered and electrons can leave the cathode. The FE source reasonably combines with scanning electron microscopes (SEMs) whose development has been supported by advances in secondary electron detector technology. The acceleration voltage between cathode and anode is commonly in the order of magnitude of 0.5 to 30 kV, and the apparatus requires an extreme vacuum (~106 Pa) in the column of the microscope. Because the electron beam produced by the FE source is about 1000 times smaller than that in a standard microscope with a thermal electron gun.

Resolution of FESEM
The image quality will be markedly improved; for example, resolution is on the order of ~2 nm at 1 keV and ~1 nm at 15 keV. To resolves a feature on the specimen surface, the beam diameter must be smaller than the feature (still containing high current density). Therefore, it is necessary to condense the electron beam. To assist in the demagnification of the beam, electromagnetic lenses are employed. The table below shows the cross over diameter, final spot diameter and demagnification for thermionic and field emitter. Since the cross over diameter in the Field Emission Source is smaller, a lower level of the beam condensation is necessary to have a probe useful for image processing. This makes the FESEM the highest resolution instrument.

The size range in Nanoscience is typically from hundreds of nanometers down to the atomic level (approximately 0.2 nm), in which the materials (nano materials) can have different or enhanced chemical/physical properties compared to the same ones at a bulk .Two main origins for these features are an increased relative surface area and the dominance of quantum effects. An increase in specific surface area will result in a corresponding increase in chemical reactivity, making some nano materials useful as catalysts to improve the efficiency of fuel cells or batteries. As the size of matter is reduced to tens of nanometers or less, quantum effects can begin to play a role, and change the material's optical, magnetic or electrical properties significantly. For example, gold nano-particles can appear blue, red, or yellow in color as a function of their size. For intended applications using nano-particles, the crucial challenge has been to make all nano-particles the same size. On the other hand, another emphasis has been placed on the shape control of nano materials because in many cases it allows one to fine tune the properties with a greater versatility than can be achieved otherwise .In face-centered cubic (fcc) metal particles, for example, the crystallographic {111} and {100} surfaces are different not only in the surface atom densities but also in surface energies, so that single-crystalline silver or gold nano-particles with sizes smaller than ~10 nm show intriguing particle shapes such as truncated octahedra or cuboctahedra . In addition, twinned metal particles are found.

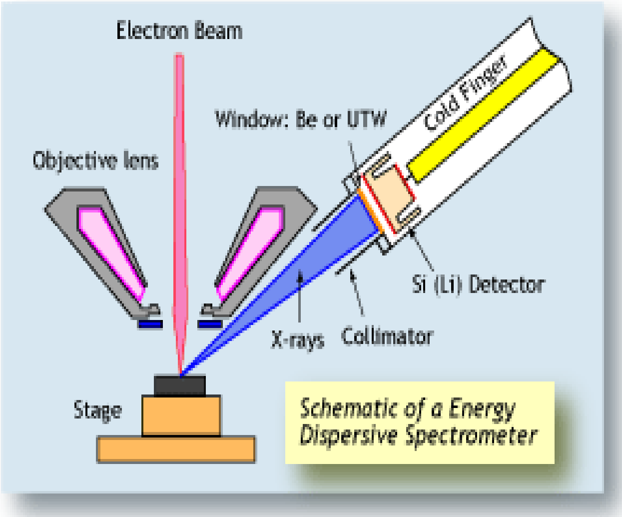
3.10FESEM

FESEM Specifications
Electron gun
Schottky field-emission gun
(Secondary electron image)
1.2 nm (at 30 kV)
3.0 nm (at 1.0 kV)
3.0 nm (at 15 kV 10mm WD, 5nA)
Accelerating Voltage
0.5 to 2.9 kV (10V steps)
3.0 to 30 kV (100V steps)
Working distance
0-40nm
Sample sizes
Maximum samples ϕ25mm and thickness 20mm

Magnification
x10 to 1,000,000x (printed as a 120mm x 90mm micrograph)
Imaging Modes
SEI (secondary electron image)
BEI to E/T Detector
BEI - Option (backscattered electron image TOPO and COMPO)

EDX or EDS:
Energy Dispersive X-ray Spectroscopy (EDX or EDS) is a relatively simple yet powerful technique used to identify the elemental composition of as little as a cubic micron of material. The equipment is attached to the SEM to allow for

elemental information to be gathered about the specimen under investigation. The technique is non-destructive and has a sensitivity of >0.1% for elements heavier than C. EDS works by detecting X-rays that are produced by a sample placed in an electron beam. The electron beam excites the atoms in the sample that subsequently produce X-rays to discharge the excess energy. The energy of X-rays is characteristic of the atoms that produced them, forming peaks in the spectrum. Please note individual elements may have more than one peak associated with them and some peaks from different elements may overlap to a certain degree. As the electron beam can be precisely controlled, EDX spectra can be collected from a specific point/particle on the sample, giving an analysis of a few cubic microns of material. Alternatively, the beam can sweep over a selected area of the sample to identify the elements in that region. In addition, line profiles and X-ray maps can be acquired which depict the elemental distribution across the specimen.



3.11 schematic of an energy dispersive spectrometer

3.7 VISCOSITY STUDIES

Viscosity is a measure of the resistance of a fluid to deformation under shear stress. It is commonly perceived as "thickness", or resistance to pouring. Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction. Thus, water is "thin", having a low viscosity, while vegetable oil is "thick" having a high viscosity.

Viscosity can be conceptualized as quantifying the frictional force that arises between adjacent layers of fluid that are in relative motion. For instance, when a fluid is forced through a tube, it flows more quickly near the tube's axis than near its walls. In such a case, experiments show that some stress (such as a pressure difference between the two ends of the tube) is needed to sustain the flow through the tube. This is because a force is required to overcome the friction between the layers of the fluid which are in relative motion: the strength of this force is proportional to the viscosity.
Different types of viscometers are

Brookfield viscometer
Saybolt viscometer
Angler's viscometer
Ostwald viscometer
Kinematic viscometer
Redwood viscometer

Redwood Viscometer
For measurement of viscosity of CuO nanoparticles in hybrid nano fluid, Redwood viscometer is used and experimental procedure fallowed by standard laboratory technique. In general Redwood wood viscometers are two types

Redwood viscometer No.1 – Universal
Redwood viscometer No.2- Admiralty

Here we are using Redwood viscometer-2 because these base fluids are more viscous. Redwood – ii viscometer and redwood i viscometer differ only in oil flow port areas. It consists of a metal cup with an axially placed orifice in the base. a metal ball or a rod can be used to close the hole. The metal cup can be heated and the oil stirred to ensure uniform temperature throughout the oil. When the ball is removed, a thin stream of oil runs into a small graduated glass flask and the time to fill the flask is recorded. This time in seconds is called "seconds redwood ii" and is a measure of viscosity. These seconds redwood ii is converted into stokes of kinematic viscosity using the empirical formula $\nu = At - (B/t)$ where a and b are viscometer constants and t is seconds redwood ii. The difference between redwood i and redwood ii viscometers lie in the dimensions of the discharge capillary (tube, jet or orifice) as given below:

VISCOMETER	DIAMETER OF FLOW PORT	LENGTH OF FLOW PORT
REDWOOD I	1.62 mm	10 mm
REDWOOD II	3.8mm	50mm

Table 3.2 Specifications of Viscometer

As per the equipment manufacturer's recommendations, the viscosity for petroleum products must be determined at the temperatures of 210 c, 37.8 0 c, 500 c, 930 c, 1210 c, 1490 c, and 2040 c. for fuel oils the minimum temperature is 490 c. for flux oils the temperature of the test be 930 c. when an oil of unknown viscosity is given it must always be tested with redwood – I viscometer. if the viscosity exceeds 2000 seconds redwood – I then the Redwood – II be used.

Working Procedure
Level the apparatus by using spirit level and adjusting the leveling screws.
Clean the oil cup thoroughly and place the ball valve in its position.
The cup must be filled with the given sample of oil up to the mark.
Fill the heating bath with water up to the marked level.
Heat the oil sample in the cup until the required temperature is attained.
Place the gravity bottle just below the oil jet and lift the ball valve.
Note down the time taken for collecting 50cc of the given oil in seconds.
Continue heating the water bath and repeat the experiment for every 50 C rise in temperature at different temperatures by finding the time taken for the collection of 50cc oil each time and tabulate the readings.

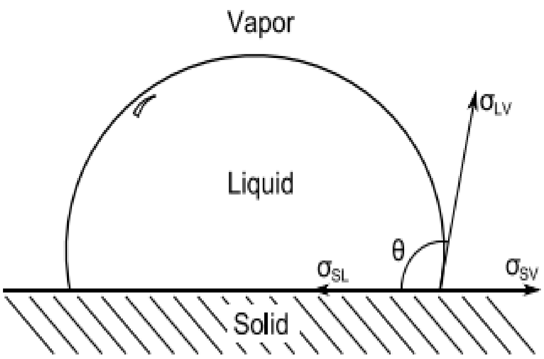
3.12 Redwood Viscometer II

Calculation formula for kinematic viscosity
Kinematic viscosity (cSt); z = At-B/t
Where A =0.247 above 80 seconds
B= 0.265 below 80 seconds
t = Redwood seconds
The effect of CuO nano particles on the other properties of castor+soyabean oil such as viscosity is the important factors which are used for correct selection of the required lubricant

3.8 CONTACT ANGLE MEASUREMENT

A definition of contact angle is needed before discussing contact angle measurement techniques. The contact angle can be defined in several ways. Qualitatively, a contact angle is the macroscopic representation of microscopic phenomena. Microscopic characteristics such as surface roughness, surface energies of the materials involved, and surface coatings play a role in the wettability of a material for a given fluid. Quantitatively, a contact angle is the interior angle formed by the substrate being used and the tangent to the drop interface at the apparent intersection of all three interfaces. This intersection is called the contact line. Figure (1.2) illustrates the tangent line and contact angle of a liquid drop on a surface. Historically a static contact angle on a flat surface is defined by the Young Equation (1.1) using interfacial surface tensions between solid and liquid, σSL, solid and vapor, σSV, and liquid and vapor, σLV. Young's equation is essentially a force balance in the horizontal direction. The contact angle may also be directly measured to calculate the ratio of interfacial surface tensions if the interfacial surface tensions are unknown.

$\sigma_{LV} \cos\theta = \sigma_{SV} - \sigma_{SL}$



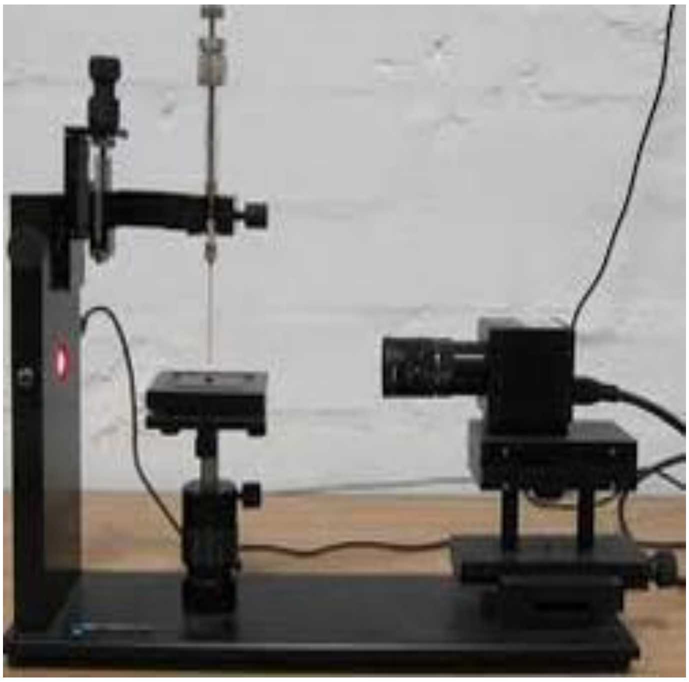
3.13 Contact angle

Young's model showing the relationship between the three interfacial tensions (solid and liquid, σSL, solid and vapor, σSV, and liquid and vapor, σLV) and the contact angle-θ

Goniometry

Goniometry uses a profile image of a drop to find contact angles. Contact angles can be directly measured using direct inspection. Other goniometer methods model the drop interface in order to find the contact angle using one of three approaches; approximations, curve fitting, or interface modeling. Direct inspection is the easiest goniometer technique to perform. An image of a drop profile is printed and the substrate surface and tangent line to the drop interface at the contact line are drawn using a straight edge. The contact angle is then directly measured using a protractor. An alternate approach would be to use a digital image and a drawing software to draw the surface and tangent lines and measure the contact angle. This technique, although easy to perform, is prone to large inaccuracies in contact angle measurements. User interpretation of the tangent line and surface as well as improper imaging and poor images lead to large variance in contact angle measurements, as illustrated in Figure. Two approximation methods are the spherical cap approximation and the small slope approach. As the name implies, the spherical cap approximation models a drop interface as a spherical cap. This approximation may only be used accurately when the drop characteristics meet a specific criterion; the drop must be small enough that gravitational effects are minimal. This criterion may be quantified using the Bond number, $Bo= \rho gl2/\sigma$, which is a ratio of capillary effects to gravitational effects, where ρ is density of the liquid, g is the acceleration due to gravity, l is the characteristic length scale, and p σ is the surface tension of the liquid. The capillary length, $Lc = \sigma/\rho g$, otherwise known as the Laplace constant, may also be used to quantify the relative effects of gravity verses capillarity. A $Bo = 1$ implies that gravitational effects and capillary effects are equal, with $Bo > 1$ meaning gravitation effects start to dominate and $Bo < 1$ meaning capillary effects start to dominate. The characteristic length scale is the radius at the drop equator for non-wetting drops (contact angles greater than 90°) and the wetted radius for wetting drops (contact angles less than 90°). The small slope approach uses a simplified Laplace-Young equation to model a drop interface. This approach does not have a size constraint like the spherical cap approximation. However, a constraint on contact angle, which must be less than 30° , is imposed. Curve fitting techniques typically model the drop interface without constraints on size or contact angle. Most curve fitting techniques require the drop interface to be defined using individual data points so a curve fitting routine or algorithm may be used. One approach is to use a polynomial fitting technique to fit the drop interface. The contact angle is determined using the tangent to the drop interface at the contact line, which is defined as the slope of the polynomial expression. Inaccuracies in contact angle measurements using a polynomial fitting technique come from inaccurately defining the tangent to the drop interface at the contact line. A more accurate approach is to model the drop interface using the Laplace-Young equation which relates the total change in pressure across a curved liquid surface, ΔP, to the two principle radii of curvature, $1/R1$ and $1/R2$, and surface tension,

$$\sigma . (1 /R1 + 1 /R2) \sigma = \Delta P$$



3.14 Goniometer

Bashforth and Adams were the first to develop a numerical solution to the Laplace-Young equation and published solutions to the equation in the form of tables. Hartland and Hartley later modified the Laplace-Young equation to study axisymmetric fluid-liquid interfaces and also published solutions to the Laplace-Young equation in the form of tables. Li et al. Numerically integrate the Laplace-Young equation using a Runga-Kutta method coded in Fortran called Axisymmetric Drop Shape Analysis (ADSA), to find contact angles. Another approach is to use a finite element method (FEM) to numerically integrate the Laplace-Young equation

3.9 TURNING USING LATHE MACHINE

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a piece of pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape.

Turning is used to produce rotational, typically axi-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed.

3.15 - Panther 1350 Lathe Machine

3.10 CUTTING PARAMETERS

In turning, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the workpiece material, tool material, tool size, and more.

Cutting feed - The distance that the cutting tool or workpiece advances during one revolution of the spindle, measured in inches per revolution (IPR). In some operations the tool feeds into the workpiece and in others the workpiece feeds into the tool. For a multi-point tool, the cutting feed is also equal to the feed per tooth, measured in inches per tooth (IPT), multiplied by the number of teeth on the cutting tool. Cutting speed - The speed of the workpiece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

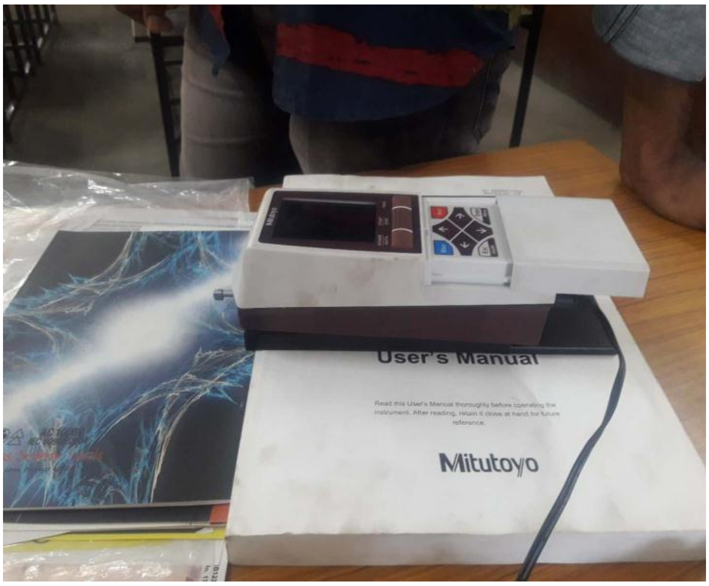
Spindle speed - The rotational speed of the spindle and the workpiece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the workpiece where the cut is being made. In order to maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.

Feed rate - The speed of the cutting tool's movement relative to the workpiece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM).

Axial depth of cut - The depth of the tool along the axis of the workpiece as it makes a cut, as in a facing operation. A large axial depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is typically machined in several passes as the tool moves to the specified axial depth of cut for each pass.

3.11 SURFACE ROUGHNESS MEASUREMENT

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.



3.16 Surface roughness tester profilometer

Roughness plays an important role in determining how a real object will interact with its environment. In tribology, rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities on the surface may form nucleation sites for cracks or corrosion. On the other hand, roughness may promote adhesion. Generally speaking, rather than scale specific descriptors, cross-scale descriptors such as surface fractality provide more meaningful predictions of mechanical interactions at surfaces including contact stiffness and static friction.

Although a high roughness value is often undesirable, it can be difficult and expensive to control in manufacturing. For example, it is difficult and expensive to control surface roughness of fused deposition modeling (FDM) manufactured parts. Decreasing the roughness of a surface usually increases its manufacturing cost. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Roughness can be measured by manual comparison against a "surface roughness comparator" (a sample of known surface roughness), but more generally a surface profile measurement is made with a profilo-meter. These can be of the contact variety (typically a diamond stylus) or optical (e.g.: a white light interferometer or laser scanning confocal microscope).

CHAPTER 4
4. RESULTS AND DISCUSSIONS

In this chapter, the results obtained from XRD, FESEM and EDS, Redwood viscometer, and contact angle goniometer are discussed. The tool tip temperature, cutting forces and surface roughness recorded during machining are graphed and discussed.

4.1 CHARACTERIZATION OF CUO NANOPOWDER

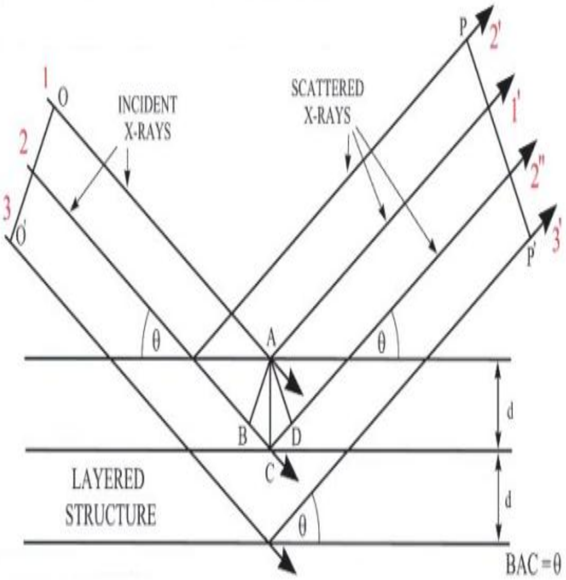
Various instruments that are used to describe physical properties, structural morphology etc, have been discussed in detail.
X-Ray Diffraction (XRD)
EDXA (Energy dispersive x-ray Analysis)
FESEM (Field Emission Scanning Electron microscope)
Properties of Cuo nanoparticles

Description	Value
Density	6.315 g/cm3
Molar mass	79.545 g/mol
Boiling point	2,000 °C (3,630 °F; 2,270 K)
Melting point	1,326 °C (2,419 °F; 1,599 K)
Dipole moment	1.9 D (24 °C)
Appearance	Brownish black
Thermal conductivity	76.5 W/m.K
Viscosity	
Dielectric constant	18.11

Table 4.1 Properties of CuO Nanoparticles

X-RAY POWDER DIFFRACTOMETER
Principle and theory of X-ray

X-ray diffraction technique is used to investigate the crystal structures and atomic spacing. Principle of X-ray diffraction is based on constructive interference of monochromatic X-rays and a crystalline sample. These X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed towards the sample. The interaction of the incident rays with the sample produces constructive interference and a diffracted ray.

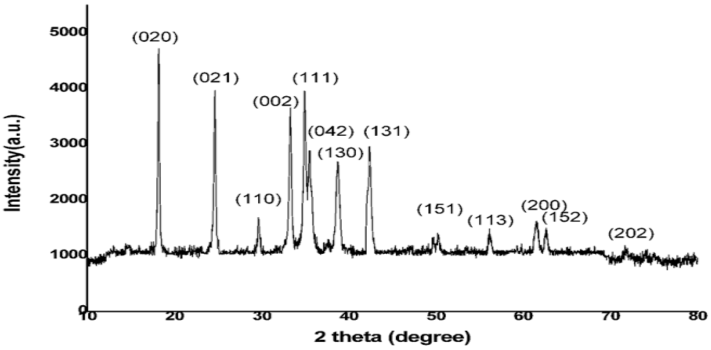


4.0 X-ray Diffraction at single crystal

XRD is used to determine the crystalline structure of NPs. The X-ray beam is transmitted into the sample and the beam is scattered by the atoms in the path of the X-ray is studied. The scattered X-rays constructively interfere with each other and this interference is calculated using Bragg's Law or the Debye Scherrer equation.

$(D=0.9\lambda/\beta \cos\theta)$

To determine various characteristics of the crystalline material (Cullity and Stock, 2001), where D is the crystal size, λ is the wavelength of X-ray, θ is the Braggs angle in radians, and β is the full width at half maximum of the peak in radians. Since all crystalline materials including the semi crystalline polymers as well as metal and metal oxide NPs have a characteristic atomic structure; it will diffract X-rays in a distinctive characteristic diffraction pattern.

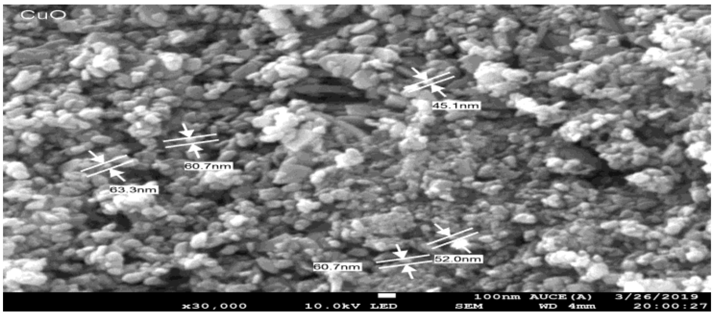


4.1X-RD analysis of CuO Nano powder

By X-RD analysis we found the elemental confirmation as well as crystalline size, we got maximum peak at (0,2,0) and crystalline size were determined by using Debye Scherrer equation we found that crystalline size approximately 22nm.

4.2 FESEM ANALYSIS

A FESEM is used to visualize very small topographic details on the surface or entire or fractioned objects. Researchers in biology, chemistry and physics apply this technique to observe structures that may be as small as 1 nanometer (= billion of a millimeter). The FESEM may be employed for example to study organelles and DNA material in cells, synthetical polymers, and coatings on microchips.



4.2 FESEM image of cuo nanoparticles

By using FESEM we found that our copper oxide particles are in nano size (less than 100 nm) and we got the size of 45.1 nm as the minimum size and 63.3 is the maximum size by FESEM analysis.

4.3 EDX ANALYSIS

To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as electrons or protons (see PIXE), or a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains ground state (or unexcited) electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was. An electron from an outer, higher-energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer.

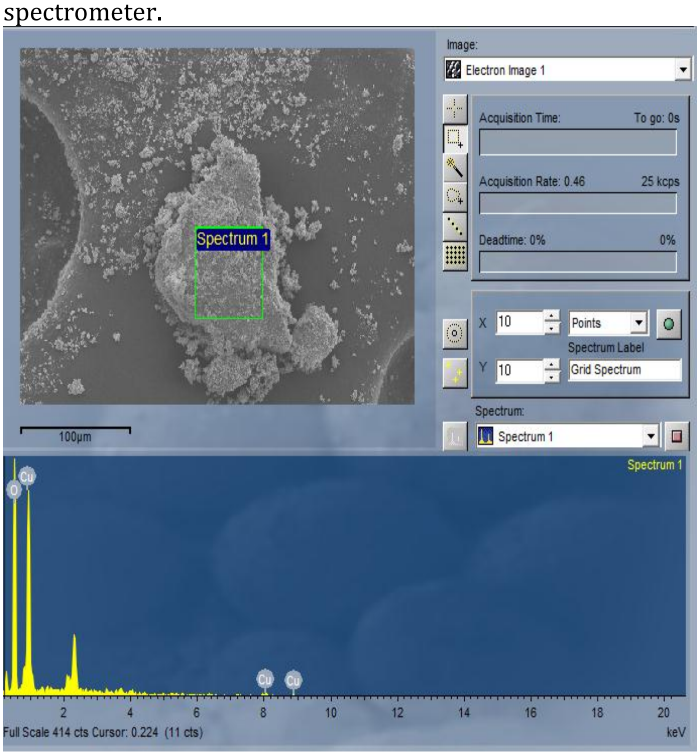


Image: Electron Image 1
Acquisition Time: To go: 0s
Acquisition Rate: 0.46 25 kcps
Deadtime: 0% 0%
X 10 Points
Spectrum Label
Y 10 Grid Spectrum
Spectrum: Spectrum 1
Full Scale 414 cts Cursor: 0.224 (11 cts)

4.4 EDX image for elemental confirmation

From EDX analysis we got the elemental confirmation that, our sample consists of copper and oxygen. Hence it is a copper oxide by atomicity.

4.4 EXPERIMENTAL RESULTS:

Readings from different Redwood Viscometer –II has at different temperatures and dynamic viscosity were calculated and graph has drawn between temperature and dynamic viscosity.

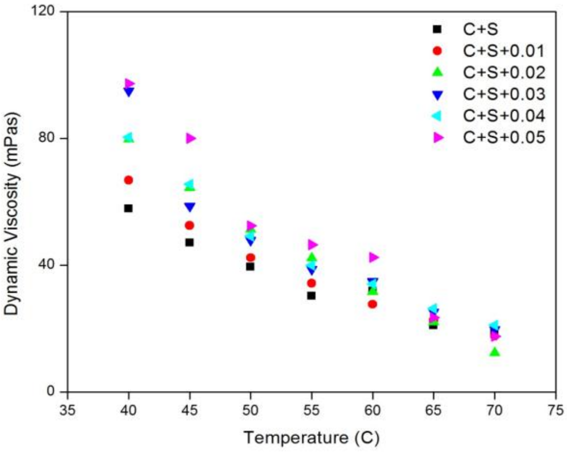
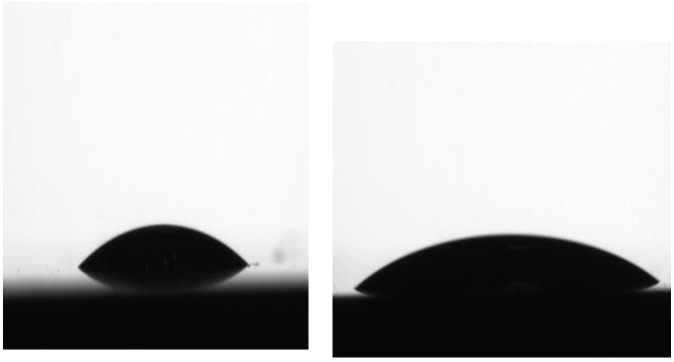


Fig : 4.4 Dynamic viscosity

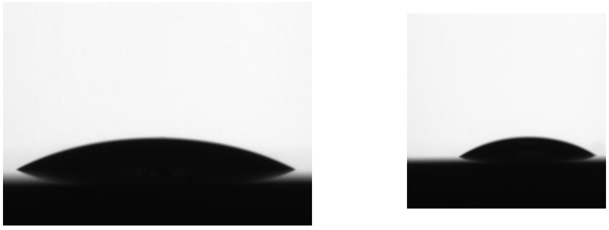
From fig 4.4 graph between temperature versus dynamic viscosity, which shows dynamic viscosity of the hybrid nanofluid decreases as the temperature increases. We can observe from graph obtained shows hybrid nanofluid with CuO 0.05% performs maximum viscosity at 400C

4.5 CONTACT ANGLE MEASUREMENTS

The contact angle of hybrid nano fluid samples was measured by using Goniometer, if we observe from the figure 4.5, as the percentage of CuO nanoparticles increases then the contact angle also decreases. Soybean and castor oil with CuO 0.05% show the least contact angle value, which means it has more wetting area over the surface and shows good lubricating property when compared to the base hybrid fluid.



Ø = 34.80 Ø = 31.40
Soybean oil + castor oil Soybean oil+castor oil +CuO 0.01%



Ø = 26.70 Ø = 25.80
S +C+CuO 0.02 % S+C+CuO 0.03%

Ø = 20.10 Ø = 16.10
S+C+CuO 0.04 % S+C+CuO 0.05%
Fig4.5 Contact angle images

4.6 TOOL TIP TEMPERATURE MEASUREMENT

The tool tip temperature was measured by using IR thermometer when CuO based hybrid nanofluid is used as a cutting fluid, during turning process temperature were recorded for an interval of every 15 seconds.

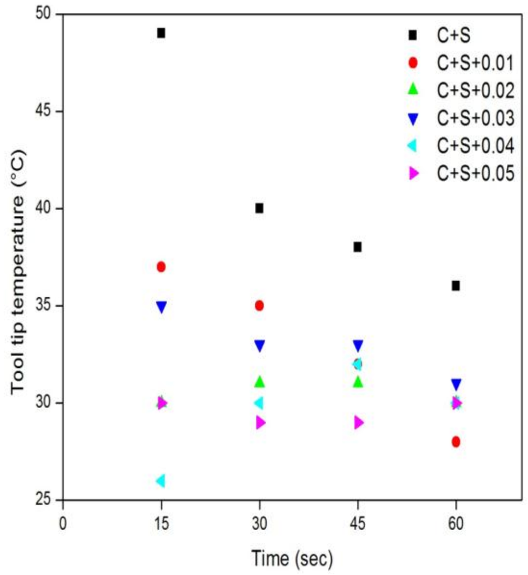
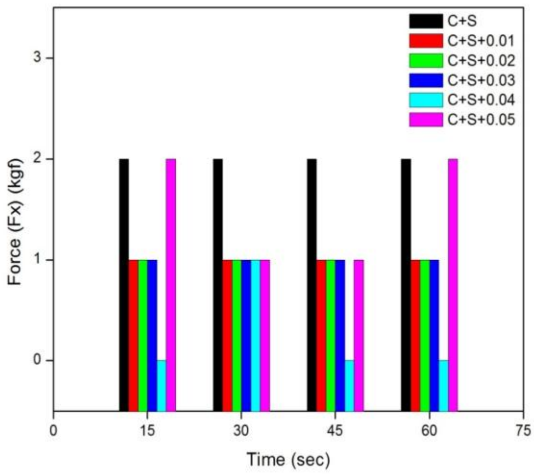


Fig 4.6 Tool tip temperature

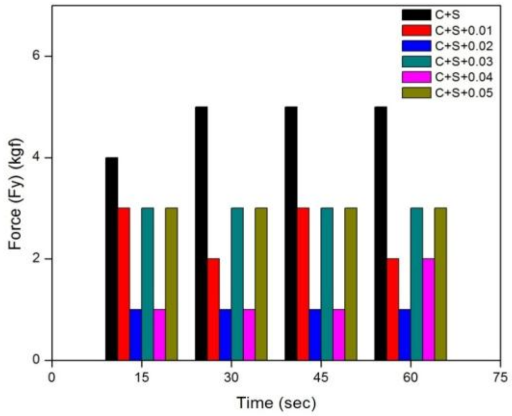
From the figure 4.6 we observed that hybrid base fluid with nano particles of CuO 0.04% shows the least tool tip temperature of 260C when compared to remaining all fluids.

4.7 CUTTING FORCES MEASUREMENT

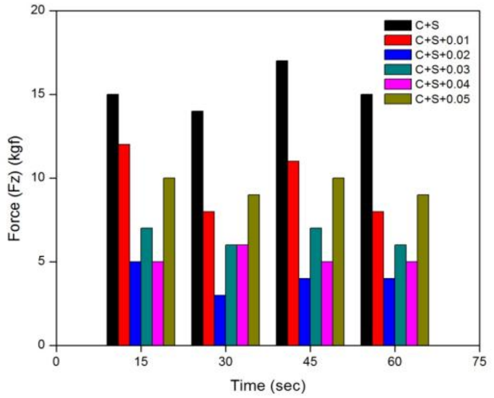
Cutting forces were measured during the turning process in all directions X,Y,Z with the help of tool dynamometer, while observing all the directions we have base fluid with CuO 0.04% shows the least cutting force values when compared to all the remaining fluids.



4.7 (a) cutting forces in x-direction



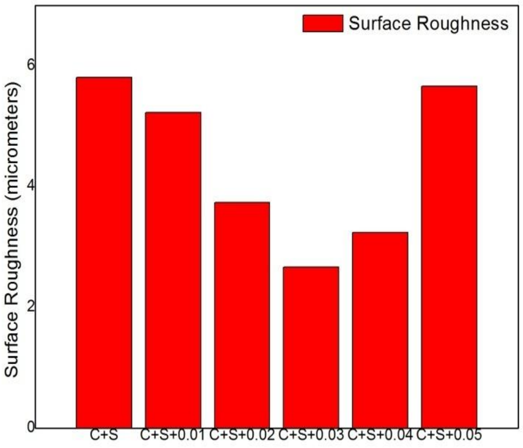
4.7 (b) cutting forces in y-direction



4.7 (c) cutting forces in z-direction

From the figures 4.7 (a),4.7(b),4.7(c) we can see all the the cutting force values of different concentrations as well as base fluid.

4.8 SURFACE ROUGHNESS MEASUREMENT



4.8 surface roughness for various fluids

Form figure 4.8 it shows that surface finish will be improved when CuO is added to hybrid fluid, with 0.03% of CuO shows good surface finish of 2.71µm

CHAPTER 5

5. CONCLUSION

The investigation has been carried out on hybrid-nanofluid with weight percentage of copper oxide (0.01%,0.02%,0.03%,0.04% and 0.05%) with base fluids soybean oil and castor oil in the ratio 1:1, copper oxide is prepared by using sol gel method, for the confirmation of particle and crystalline size X-RD and FESEM will be done then nano particles were dispersed into base fluid after that contact angle, tool tip temperate, cutting forces during the machining process and surface roughness were measured which defines the quality of the product

The experimentation is carried gives the following results: X-RD testing gives the crystalline size gives 22nm(approx.) FESEM and EDX gives size of the nano particles under the range of 45-60 nm

Viscosity is studied by using Redwood Viscometer-II which gives base fluid with 0.05% of CuO shows more viscosity when compared to remaining all fluids

The contact angle of nanofluids has decreased with increase in concentration of nanoparticles in base fluid, and 0.05 wt.% nanofluid has the least contact angle. The decrease in contact angle increases the wetting area thereby increasing the lubrication effect.

Tool tip temperature has decreased when nanofluids were used as cutting fluids, compared to base fluid (castor +

soybean oil). The least tool tip temperature was recorded when 0.05 wt.% nanofluid was used as cutting fluid.
When compared to base fluid, fluid with 0.02wt% gives least cutting forces

Surface finish has enhanced at CuO 0.03% with base oil, when compared to so hybrid base fluid

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