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Investigation the Performance of Cutting Machines using Nano Fluids as Coolant

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Abstract

This thesis explores the effectiveness of aluminum oxide (Al2O3) and copper oxide (CuO) nanoparticles as coolants in metal cutting on a lathe machine. It compares these nanofluids to conventional cutting fluids in terms of machinability. Experiments were conducted with stainless steel workpieces using conventional fluids and nanofluids with 0.2%, 0.5%, and 0.8% concentrations of Al2O3 and CuO nanoparticles. The study assessed temperature, tensile strength, hardness, tool wear, and chip morphology. Findings indicate that nanofluids reduce temperatures and decrease tool wear more effectively than conventional fluids. For Al2O3, optimal improvements were observed at 5% concentration, while higher concentrations led to deteriorations. CuO nanoparticles showed continuous reductions in temperature up to 8%, with increased tensile load and hardness at this concentration. Chips produced with nanofluids were longer and less fragmented. Overall, nanofluids demonstrate potential as sustainable coolants, offering benefits over traditional fluids. Further research is needed to optimize nanofluid formulations and expand their applications.
Keywords: *cutting fluids, nanofluids, aluminum oxide, copper oxide*

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1. Introduction

From ancient times man tried to meet his needs in different ways Including the conversion of materials available in his environment into products that meet his needs, as there was something of modest industrial production in terms of its capabilities and thus modest qualities and quantities of products where manual tools were used at that time.

Until the industrial revolution took place, which began to bring about an evolution in the production methods as well as the tools and machines used in industry, due to the increasing human requirements and the use of minerals and iron as an essential element in production, methods of converting raw materials into products and into semi-manufactured materials by machines appeared by cutting difficult parts of the metal, it is called chip with the development of industries and the need for large quantities of production, and then the complexity of products and the use of more hard minerals, it shows the importance of using coolant fluids to reduce the heat generated between the tools and the working piece.

Therefore, the need to develop a conventional cooling fluid system seemed to obtain better thermal properties of the liquid as well as to obtain better properties for the work piece and to maintain the life of tools. Nanomaterials make the foundation of Nano science and nanotechnology. Nanomaterial research has attracted a great number of scientists and the field has seen explosive growth over the years (H. Tschatsch, 2009).

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Nanomaterial are extremely small, at least in one dimension. To be classified as a nanomaterial at least one dimension (width, length or height) needs to be less than 100 nanometers. Once again, a nanomaterial is one billionth of a meter or 1000 million times smaller than a meter. It is so small that it is 100,000 times smaller than the diameter of a human hair.

Nanomaterials are a subject of great interest due to unique properties these materials show. Scientists have observed that nanoparticles show unique mechanical, optical, magnetic and electrical properties that are not seen in their bulk counterparts. These materials promise potential for great achievements in fields such as electronics, medicine, transportation, and textiles.

Although the subject of nanomaterial may seem futuristic, number of nanoparticles occur naturally in higher abundance than most of us think. There are many Nano sized particles in fine sand and dust. Volcanic ash contains large number of nanoparticles and even viruses that are quite plentiful in our surroundings can be classified as nanoparticles. There are also manmade nanoparticles, which are made incidentally from certain situations like in engine smoke, burning, factory smoke, etc. However, engineered nanoparticles, deliberately synthesized by humans usually with a specific objective in mind, holds a particular interest (M.Groover, 2010).

Nano materials are classified according to the length scale of each of its dimensions. The definition states that at least one dimension of a nanomaterial should be in between 1 to 100 nm. Accordingly (A. Youssef.,2008). Literature Review (Shokoohi ,2016), In this study, the effect of nanofluids on various cutting processes and cutting parameters as cutting forces, surface roughness and work piece temperature was studied. (Khandekar ,2012), He prepared nan fluid using 〖AL〗_2 O_3 (1% by volume in base fluid). The prepared mixture consists of Servo Cut ‘‘S’’ plus additives plus AL2 O3 nanoparticles and Water. (Setti ,2012), they studied the performance of nanofluid as cutting fluid in grinding operation under Minimum Quantity Lubrication technique. (Prasad ,2013), They prepared the nanofluid by the inclusion of graphite powder (0.0 %, 0.1, 0.3 and 0.5% by weight) nanoparticles into water-soluble oil. (Saravanakumar,2014), They used synthesized silver nano particles dispersed in conventional cutting fluid. The experiment was conducted on the turning operation. (Shailesh,2015), He presented experimental study on the enhancement effect of AL2 O3 nanoparticles dispersed in base fluid as cutting under Minimum Quantity Lubrication technique in turning operation. (Ramesh,2016), This paper presented the investigation of the performance of AL2 O3 addition in base fluid. They prepared nanofluid used as cutting fluid on turning operation and it effect on flank wear and crater wear were evaluated.

2. Preparation of Nanoparticles

Two types of Nano particles were selected Aluminum Oxide and Copper Oxide.

2.1 Aluminum Oxide Nanoparticles

Alumina has many appealing properties, which makes the material interesting for applications in many different areas. Alumina especially has a high melting point, high strength, corrosion resistance, chemical stability, low thermal conductivity and good electrical insulation properties. (B.E. Yoldas,1995) as a type of important structural ceramic material, alumina has applications in absorbent, catalyst, carrier and reinforcement of ceramic composites. Alumina occurs in nature as the minerals, corundum (Al2O3); diaspore (Al2O3.H2O); gibbsite (Al2O3.3H2O); and most commonly as bauxite, which is an impure form of gibbsite. Alumina exists in a number of crystalline phases (polymorphs), three of the most important being γ, θ, and α. (D. Mishra,2000) The γ-alumina phase is an unstable phase, and this phase of alumina is used as catalyst and catalyst support because of it shows high surface area. The lattice structure of gamma alumina has two different lattices, the first lattice is comprised of aluminum ions, it is formed from octahedral and tetrahedral interstitial locations, and the oxygen lattice is formed with the face center cubic structure (K.P. Prodromou,1995).

2.1.1 Preparation Method of Aluminum Oxide Nanoparticles:

Chemical routes for production of these materials Include sol–gel, hydrothermal processing and control precipitation of boehmite obtained from aluminum salts, oxides and metallic Powders. Gamma alumina nanoparticles were prepared by sol gel method using aluminum nitrate precursor and ammonium carbonate route possess spherical Nano-sized particle (S. Music,1990).

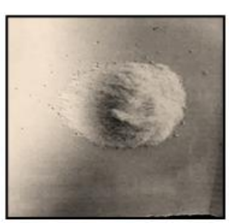

Fig.2.1 alumina nanoparticles (S. Music,1990).

2.1.2 Properties of Aluminum Oxide Nanoparticles:

Table 2.1 Properties of alumina nanoparticle (K.P. Prodromou,1995).

Appearance (Color)	White
Appearance (Form)	powder
Avg. Size (TEM)	less than 50 nm
Shape (TEM)	Spherical - like Shape

2.2 Copper Oxide Nanoparticles

The oxides of transition metals are an important class of semiconductors, which have applications in magnetic storage media, solar energy transformation, electronics and catalysis (J.C. Mallinson,1987) Among the oxides of transition metals, CuO has attracted much attention because it is the basis of several high-T_C superconductors. CuO is a semiconducting compound with a narrow band gap and used for photoconductive and photo-thermal applications (A.E. Rakhshni,1986) . However, up to now, the reports on the preparation and characterization of Nano-crystalline CuO are relatively few to some other transition metal oxides such as zinc oxide, titanium dioxide, tin dioxide and iron oxide. Some methods for the preparation of Nano-crystalline CuO have been reported recently such as the sono-chemical method (R.V. Kumar,2000), sol–gel technique (A.A. Eliseev,2000), one-step solid-state reaction method at room temperature (J.F. Xu,2000), electrochemical method (K. Borgohain,2000), thermal decomposition of precursors(J.Q. Yu,1999), and co-implantation of metal and oxygen ions(S. Nakao,2000), and so on.

2.2.1 Preparation Method of Copper Oxide Nanoparticles:

Copper oxide nanoparticles have been prepared via sol-gel technique. This technique offers some advantages in stabilizing the as-prepared nanoparticles (Trausty, 2014), in this method CuO NPs involves the addition of an aqueous NaOH solution to the solution of Copper acetate to form a precipitate.

Fig.2.2 Copper oxide nanoparticles (E.P. Wolhfarth,1980)

2.2.2 General Properties of Copper Oxide Nanoparticles:

Table 2.2 Properties of copper oxide nanoparticles (T. Mitsuyu,1982).

Batch number	006
Appearance (Color)	Dark brown to Black
Appearance (Form)	Powder

2.3 Preparation of Nano-cooling fluid

Experiments were performed using minimal amount lubrication (MQL) with varying nanoparticle concentrations. Traditional cutting oil, water is used as the base fluid. Operating conditions were fixed with varying concentrations of nanoparticles to establish a comparison between them. Two types of nanoparticles have been used with different concentrations, the first type is aluminum oxide and the second type is copper oxide.

Seven different types of MQL environments were used for investigation and those are:

Table 2.3 types of minimal amount lubrication

1	Conventional cutting fluid
2	Nano fluid base water Contains 0.2 vol% inclusion of AL_2O_3 nanoparticles
3	Nano fluid base water Contains 0.5 vol% inclusion of AL_2O_3 nanoparticles
4	Nano fluid base water Contains 0.8 vol% inclusion of AL_2O_3 nanoparticles
5	Nano fluid base water Contains 0.2 vol% inclusion of CuO nanoparticles
6	Nano fluid base water Contains 0.5 vol% inclusion of CuO nanoparticles
7	Nano fluid base water Contains 0.8 vol% inclusion of CuO nanoparticles

2.3.1 Preparation of Suspensions:

1- Prepare 1L of 0.2% w/v concentration weigh out 2gm of dried nano alumina and then suspended in 1L of Distilled water with sonication for 15min.

For 0.5% weigh out 5gm and for 0.8% weigh out 8gm with repeationg the previous steps.

Fig.2.3 Nano fluid base water Contains AL_2O_3 nanoparticles

2- Prepare 1L of 0.2% w/v concentration weigh out 2gm of dried nano copper oxide and then suspended in 1L of Distilled water with sonication for 15min.

For 0.5% weigh out 5gm and for 0.8% weigh out 8gm with repeating the previous steps.

Fig.2.4 Nano fluid base water Contains CuO nanoparticles

3. Experimental Work

3.1 Machining the Samples on the Lathe Machine

The samples where machining on a lathe machine with the specified dimensions required for the tensile test. Seven samples were carried out with different proportions of coolant. One sample was carried out with a conventional coolant and six samples with a Nano cooling liquid. Three samples with different proportions of aluminum oxide and three samples with different proportions of copper oxide, and all samples were carried out. At the same conditions at room temperature and at the same cutting condition

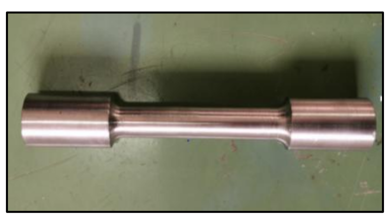

Fig.3.1 samples where machining on a lathe machine

3.2 Tensile Testing Machine

Machine Specifications: Capacity range: (0 – 100) KN**,** uncertainty: $\pm 0.001\%$**,** Machine functions: tension, compression, bending.

Fig.3.2 Tensile testing machine

The seven samples were tested on the tension machine before they were machining on the lathe machine to find out the extent of the effect of the different cooling fluids used during the machining process on the mechanical properties of the samples.

Fig.3.3 sample after tested in Tensile testing machine

3.3 Hardness Testing Machine

HMV-2000 SHIMADZU Micro Vickers hardness tester. Standardized automatic length measurement function using a CCD camera built in.

The seven samples were tested on the hardness machine before they were machining on the lathe machine to find out the extent of the effect of the different cooling fluids used during the machining process on the surface hardness of the samples.

Fig.3.4 Hardness testing machine

4. The effect of different concentrations on the different machinability characteristics and on mechanical properties of work piece

4.1 Load Elongation Curve

4.1.1 Load Elongation Curve of AL_2O_3

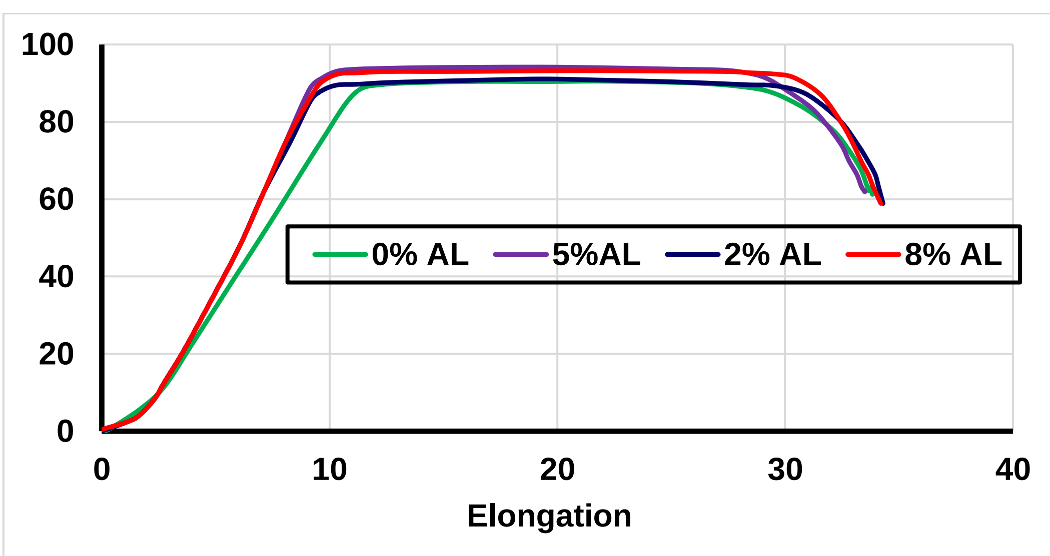

Fig.4.1 Load Elongation Curve of AL_2O_3

It is clear from the curve the increase in the maximum load for the concentration of 5% aluminum oxide followed by 8% then 2%. As well as the maximum elongation incident to the sample. Therefore, the maximum elongation of the sample was 2% aluminum oxide with a value of 34.3. Then after that, it was sampled by 8% with a value of 34.2. and a sample of 5% came with an elongation value less than The traditional sample, where the elongation value of the traditional sample was 33.8, and the elongation value of the 5% sample was 33.5.

The results of Proof stress (0.2%) are as follows:

The sample of 5% aluminum oxide was the highest with a value of 690.98, and then the sample of 8% with a value of 683.94, and the lowest value was the value of a sample of 2% with a value of 668.38, although it was higher than the value of the traditional sample, which reached a value of 662.58.

(A) Maximum Tensile Load

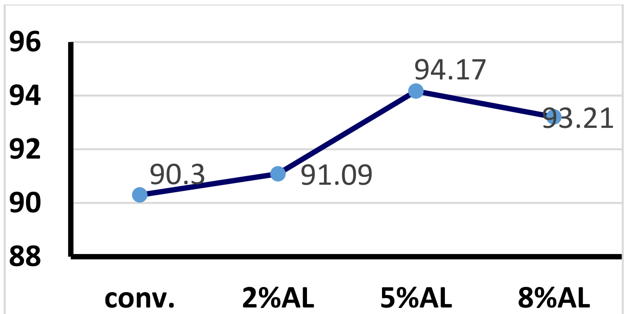

Fig. 4.2 Maximum tensile load of AL_2O_3

When conducting a tensile test for samples produced with different percentages of aluminum oxide as a Nano-cooling liquid, we find that the maximum tensile load has increased in its sample (2% AL).

By 790N, and when increasing the concentration ratio to (5%AL), the maximum tensile load increased by 3870N from the traditional sample, while when the concentration increased to (8%AL), a noticeable decrease was found in the maximum tensile load from the sample (5%AL), as the maximum tensile load reached an increase of 2910 N over the conventional sample.

Table 4.1 tensile test results for AL_2O_3

	Max. force (KN)	Proof stress (0.2%)	Ultimate tensile stress (MPa)	Elongation (%)
conventional	90.3	662.58	736.2	33.8
2% AL_2O_3	91.09	668.38	742.64	34.3
5% AL_2O_3	94.17	690.98	767.76	33.5
8% AL_2O_3	93.21	683.94	759.93	34.2

4.1.2 Load Elongation Curve of CuO

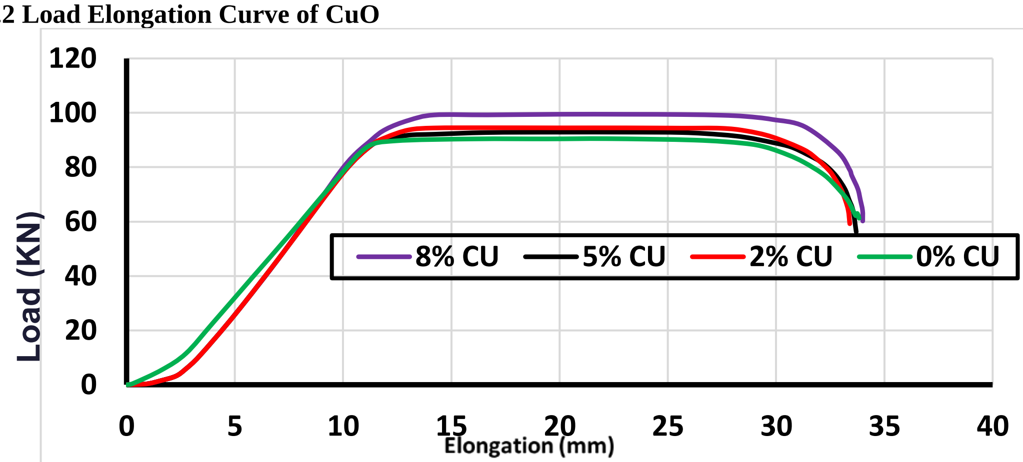

Fig.4.3 Load Elongation Curve of CuO

From the curve the increase in the maximum load for the concentration of 8% copper oxide followed by 2% then 5% as well as the maximum elongation incident to the sample. so the maximum elongation of the sample was 8% copper oxide with a value of 34.0 and a samples of 5% and 2% comes with an elongation value less than The traditional sample where the elongation value of the traditional sample was 33.8 while the elongation value of the 5 % sample was 33.7 and 2% sample was 33.4.

The results of Proof stress (0.2%) are as follows:

The sample of 8% copper oxide was the highest with a value of 728.18, and then the sample of 2% with a value of 693.55, and the lowest value was the value of a sample of 5% with a value of 681.59, although it was higher than the value of the traditional sample, which reached a value of 662.58.

(A) Maximum Tensile Load

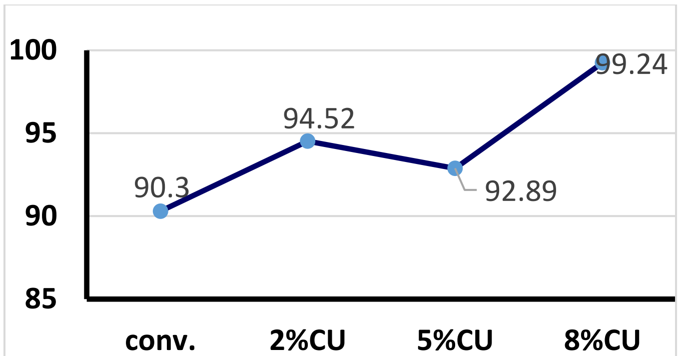

Fig.4.4 Maximum tensile load of CuO

When conducting a tensile test for samples produced with different percentages of copper oxide as a Nano-cooling liquid. We find that the maximum tensile load has increased in its sample (2% CU) by 4220N, and when increasing the concentration ratio to (5%CU), the Maximum tensile load increased by 2590N from the traditional sample while when the concentration increased to (8%CU), and the maximum tensile load reached an increase of 8940 N over the conventional sample.

Table 4.2 tensile test results for CuO

	Max. force (KN)	Proof stress (0.2%)	Ultimate tensile stress (MPa)	Elongation (%)
conventional	90.3	662.58	736.2	33.8
2% CuO	94.52	693.55	770.61	33.4
5% CuO	92.89	681.59	757.32	33.7
8% CuO	99.24	728.18	809.09	34

4.2 Hardness

After hardness test on samples we found increase in hardness when used Nano fluid as coolant in both case AL_2O_3 and CuO.

Table 4.3 hardness test results (HV)

conventional	2% AL_2O_3	5%AL_2O_3	8%AL_2O_3	2%CuO	5%CuO	8%CuO
328.3	541	521	462.67	389	336.33	346

4.2.1 Hardness test by using AL_2O_3 Coolant

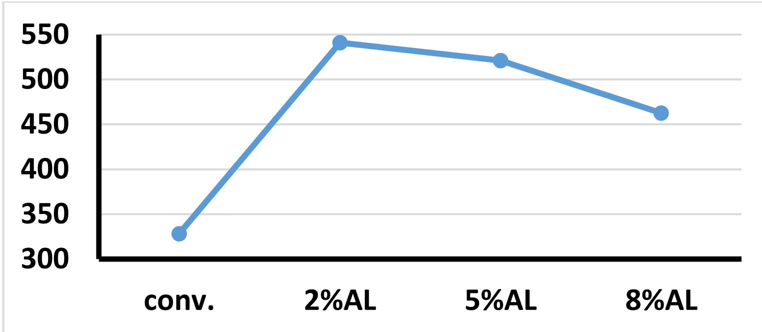

Fig.4.5 hardness of AL_2O_3

When conducting a hardness test for samples produced with different percentages of aluminum oxide as a Nano-cooling liquid. we find that the maximum hardness has increased in its sample (2% AL) By 541HV, and when increasing the concentration ratio to (5%AL), the hardness decreased and it record 521HV, while when the concentration increased to (8%AL), a noticeable decrease was found in the hardness from the sample (5%AL), as the hardness reached an decrease of 462.67 . While the traditional sample record 328.33 H.

4.2.2 Hardness test by using CuO Coolant

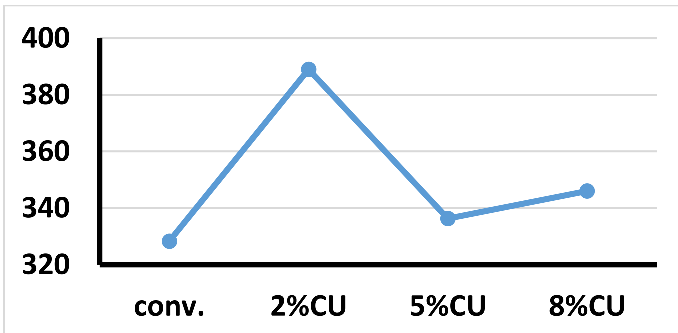

Fig.4.6 hardness of CuO

When conducting a hardness test for samples produced with different percentages of copper oxide as a Nano-cooling liquid. we find that the maximum hardness has increased in its sample (2% CuO) By 389HV, and when increasing the concentration ratio to (5%AL), the hardness decreased and it record 336.33HV, while when the concentration increased to (8%AL), a noticeable increase was found in the hardness by 346 HV while the traditional sample record 328.33 HV.

5. Conclusion

1-This thesis presents an experimental investigation on the effect of using aluminum oxide (Al2O3) and copper oxide (CuO) nanoparticles as coolants during the machining of stainless steel.

2- Different concentrations of Al2O3 and CuO nanoparticles were dispersed in water to prepare nanofluids for minimum quantity lubrication (MQL).

3- The effects of different nanofluid concentrations on cutting forces, temperature, tensile strength, hardness, tool wear and chip morphology were studied.

4- The results showed that nanofluid coolants reduced the cutting forces, temperature, tool wear and improved the tensile strength compared to conventional coolant. 5% Al2O3 nanofluid exhibited the best performance in increasing tensile strength while 8% CuO nanofluid showed the maximum reduction in cutting forces and temperature.

5- The hardness also improved with the nanofluid coolants compared to conventional coolant. The chip morphology changed from continuous chips with conventional coolant to broken chips with nanofluid coolant. The study concludes that nanofluid coolants containing Al2O3 and CuO nanoparticles improve the machinability characteristics significantly compared to conventional coolants.

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