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The Relative Influence of Zinc Ferrite and Copper Ferrite Nanolubricants on the machining of AISI 1040 steel

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ABSTRACT: Turning is one of the most common manufacturing process used for metal cutting. Generation of high temperatures at the cutting zone during machining is one of the crucial problems, which adversely affect the tool life and surface finish of the component. Generally, cutting fluids and solid lubricants are used to overcome this problem. Now-a-days nano level particles of solid lubricants are being used in machining especially in the turning and grinding operations.

The present study investigates the effect of zinc ferrite and copper ferrite nanoparticles mixed with SAE50 base oil separately when used as lubricant in the turning of AISI 1040 steel under variable machining conditions and their influence on Main cutting force, Temperature and surface roughness of the component. It also aims at finding out the best weight percentage of nanoparticles added to base oil and to find out the nanoparticulate lubricating oil that shows better performance in machining.

KEYWORDS: zinc ferrite, copper ferrite, lubrication, turning, SAE50

I. INTRODUCTION

Machining is a common and versatile manufacturing process. During machining, friction between the tool and work-piece gives rise to high temperatures. The main problem associated with any metal cutting operation is the presence of undesirable elevated temperature at the cutting zone. To reduce friction and wear at tool interface, lubricants are used. Now-a-days nanolubricants are used in industries to reduce friction. Minimum Quantity Lubrication(MQL) is one of the best methods for applying nanolubricants in machining operations. Unlike normal flood cooling, this technique is free from fluid disposal problem as it takes very small quantity for machining. This technique involves significantly lesser amount of cutting fluid. Due to the obvious advantages found in the nano fluids, the present investigation is carried out with Zinc Ferrite ($ZnFe_2O_4$) and Copper Ferrite ($CuFe_2O_4$) nanoparticles added to SAE 50 base oil in the machining of AISI 1040 steel.

II. REVIEW OF LITERATURE

MQL is an effective and environmental-friendly solution and is widely used in the machining processes. MQL helps to increase the quality of the surface finish [1-2], get better tool life, reduce tool wear, decrease cutting temperature and decrease the cost of lubrication. The efficiency of MQL has already been confirmed in many studies and application of turning and milling processes. Applied lubricants such as mineral oils, synthetic esters, fatty alcohols, etc. are very common in machining. Even vegetable oil has been proven to be an effective lubricant in machining [3,4]. Krishna and Rao [5-6] used boric acid during turning of AISI 1040 steel using HSS and carbide cutting tools. Boric Acid improved the process performance by reducing the cutting forces and tool wear. It has shown improvement even

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in surface finish. Machining performance was improved with reduced particle size while using dry solid lubricants. They also reported improvement in machining performance with boric acid suspension in SAE40 oil.

Many researchers have been working to achieve eco-friendly sustainable manufacturing system. Solid lubricants like boric acid, MoS_2, graphite, etc. were used in machining applications as alternative to cutting fluids. Shaji and Radhakrishnan [7-9] investigated the effect of graphite, CaF_2, BaF_2 and MoS_2 in grinding at various cutting conditions. The tangential force and surface roughness were lower and normal force was higher compared to those in the conventional grinding. But, wheel clogging is major hindrance in obtaining more desirable results. R.F.Avila, A.M Abrao [10] investigated the performance of various types of cutting fluids in turning on hardened AISI 4340 steel using mixed alumina inserts. The experiments were conducted on a CNC lathe. The cutting fluids considered for investigation are emulsion without mineral oil, synthetic, and emulsion containing mineral oil. The results concluded that the machining using emulsion without mineral oil gave better tool life when compared to dry cutting.

Boric acid powder was used to conduct Pin on Disc (POD) experiment with particle sizes ranging from 350 microns to 100 nm. Ramana et al. [11] have compared the effect of particle size of boric acid powder used in the machining of hardened steel and concluded that nano sized particles as lubricant showed inverse phenomenon as compared to that when micron level particles are used. As the properties of materials change with respect to spatial dimensions from micron to nano size, the tribological performance of the solid lubricant used in metal cutting, has become questionable.

III.EXPERIMENTATION

In the present investigation, the influence of zinc ferrite and copper ferrite nanoparticles mixed separately with SAE 50 base oil when used as lubricants in turning of AISI 1040 steel, was studied. The variations of main cutting force, Temperature and surface roughness were studied during the experimentation.

The main cutting force was measured using a calibrated strain gauge dynamometer. The representative temperature was measured using a thermocouple, which is placed at the bottom of the tool holder. A calibrated surface roughness tester was used to find out the surface roughness.

The experimental setup was developed as shown in fig.1 to achieve the dispensing of the lubricant. It consists of a lathe machine connected with a reservoir attached with a stirrer. Initially, zinc ferrite nanoparticles were added to SAE 50 oil and were mixed thoroughly using an ultra sonicator (see fig.2). The lubricant was poured into the reservoir. The stirrer was switched on when machining was carried out to overcome the effect of agglomeration of the solid particles in the carrying medium. Main cutting force, Temperature and surface finish were measured. Following the similar procedure, the experimentation was carried out using copper ferrite nano particulate SAE50 oil as lubricant.

Fig1.Experimental setup

Fig2. Ultrasonicator

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Specifications of the equipment

Machine tool	Turn Master – (PSG Make)
Cutting tool	P4 Uncoated carbide tool
Lathe tool dynamo meter	Make Techno lab Associates, India, strain gauge (0-300 kg)
Thermocouple	K-type
Surface roughness tester	Tally surf

IV. EXPERIMENTAL RESULTS

Initial machining conditions considered were cutting velocity 70m/min, depth of cut 0.25mm and feed rate 0.14 mm/rev. At first machining was carried out with dry and SAE50 oils. Following table shows the results of the above mentioned conditions.

Cutting parameter	Dry Machining	SAE50
Temperature (^oC)	150	120
Cutting Force (N)	119	75
Surface Finish (μ)	6.4	5

Following results indicate the changes in machining properties when zinc ferrite and copper ferrite nanoparticles are mixed with SAE 50 oil separately and used as lubricants in the machining of AISI 1040 steel. The sample weight percentages considered were 0.1%, 0.2%, 0.4%, 0.6% and 0.8% in 100 ml of SAE50 oil for the present investigation.

Experiments have been conducted to know the influence of different weight percentages of nanoparticles added to SAE50 oil on temperature and Main cutting force in the machining of AISI 1040 steel. The results obtained in the experiments are summarised below.

Experiments have been conducted to know the variations in temperature with 0.1 wt%, 0.2 wt%, 0.4 wt%, 0.6 wt% and 0.8 wt% of Zinc Ferrite nanoparticles in SAE50 oil with passage of time from 1 sec. to 4 secs.

Zinc ferrite nanoparticles **Copper ferrite nanoparticles**

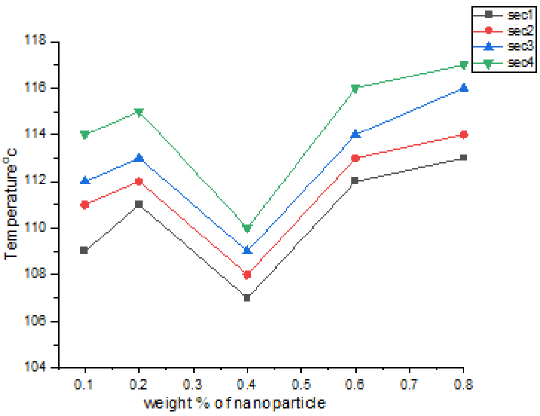

Fig. 1(a)

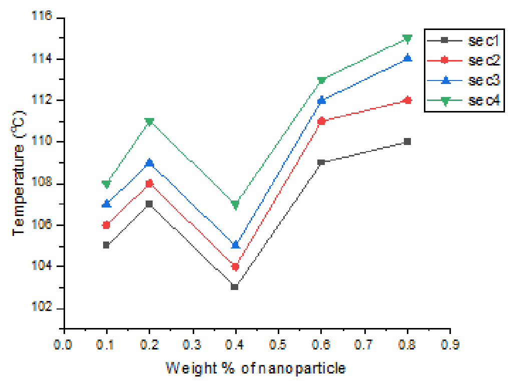

Fig.1(b)

Influence of weight percentage of nano particles on Temperature

The above results in Fig. 1(a) & 1(b) indicate that there is increase in temperature from 0.1 wt% to 0.2 wt% of Zinc Ferrite and copper ferrie nanoparticles in SAE50 oil and then a gradual decrease in temperature from 0.2 wt% to 0.4 wt%. Again, there is increase in temperature from 0.4 wt% to 0.8 wt% during the passage of time from sec.1 to

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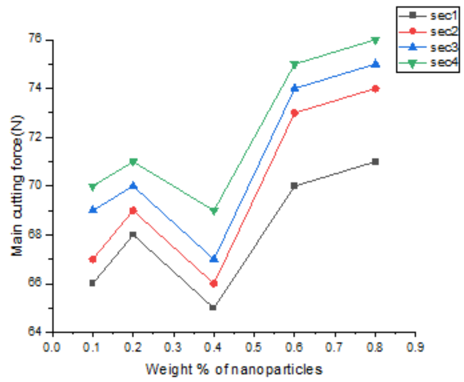
sec.4. The temperature is observed minimum for 0.4 wt% of Zinc Ferrite and copper ferrite nanoparticles in SAE50 oil for all the four intervals of time considered for the investigation.



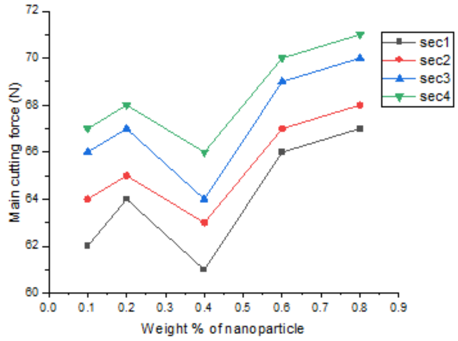


Fig. 2(a) Fig. 2(b)

Influence of weight percentage of nanoparticles on Main Cutting force

The above results in Fig.2 (a) & 2(b) indicate that there is a gradual increase of the Main cutting force from 0.1 wt% to 0.2 wt% of zinc ferrite and copper ferrite nanoparticles added separately to SAE50 oil and then a gradual decrease in the Main cutting force from 0.2 wt% to 0.4 wt%. Again, there is increase in the Main cutting force from 0.4 wt% to 0.8wt% during the passage of time from sec.1 to sec.4. The Main cutting force is observed minimum for 0.4 wt% of Zinc Ferrite and copper ferrite nanoparticles in SAE50 oil for all the four intervals of time.

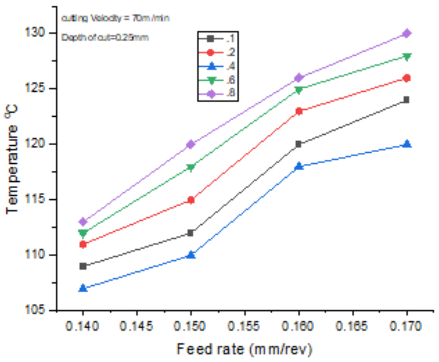


Fig3(a)

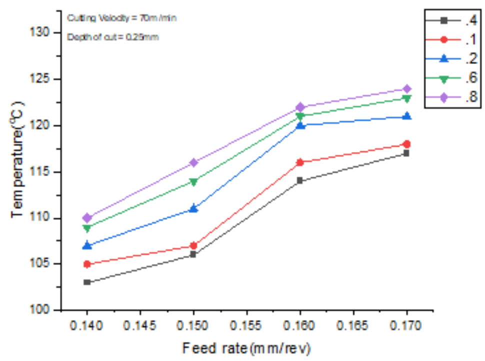


Fig3(b)

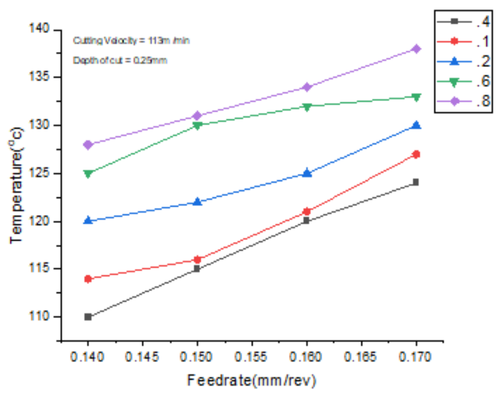


Fig3(c)

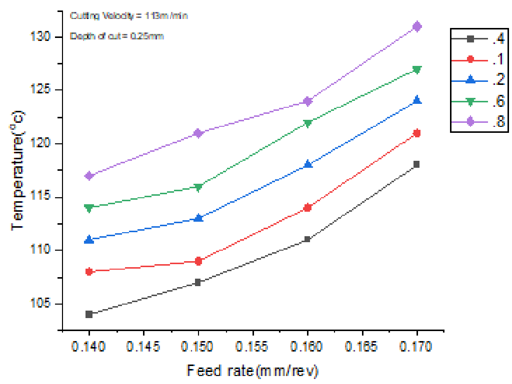


Fig3(d)

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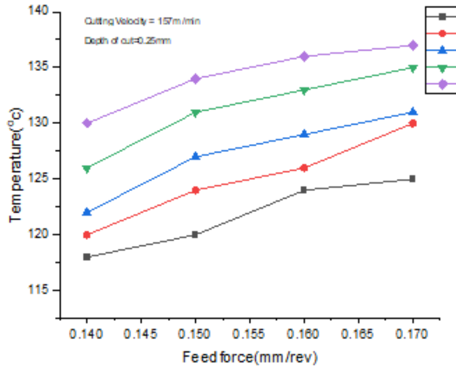

Fig 3(e)

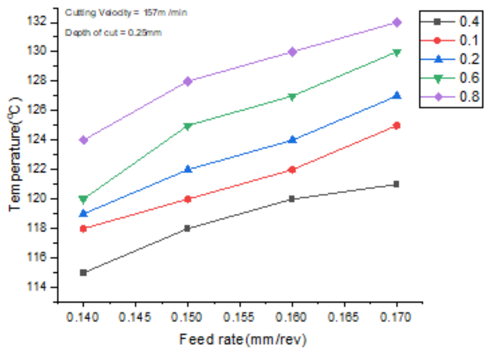

Fig 3(f)

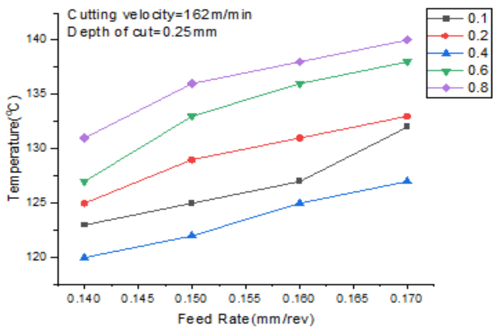

Fig3(g)

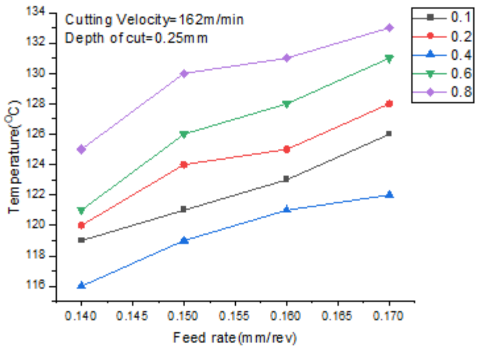

Fig. 3(h)

Influence of feed rate on temperature

The above results in Fig.3(a) to 3(h) indicate that there is a gradual increase of temperature with the increase in the feed rate from 0.14 mm/rev to 0.17 mm/rev. for all the weight percentages of nanoparticles. The temperature is observed minimum for 0.4 wt% of Zinc Ferrite and copper ferrite nanoparticles added to SAE 50 oil separately.

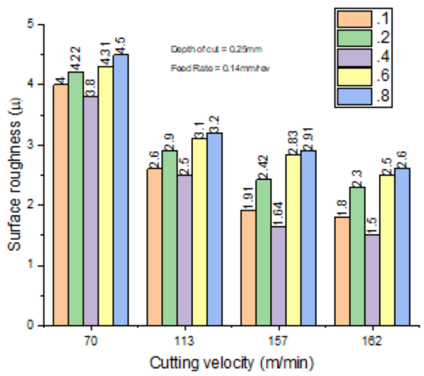

Fig4(a)

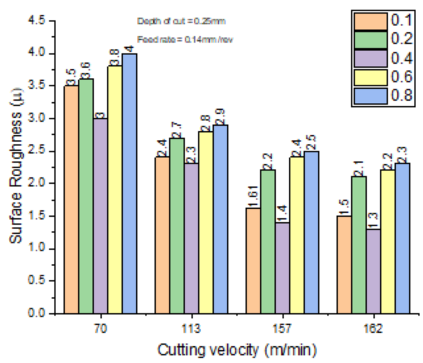

Fig4(b)

Influence of cutting velocity on surface roughness

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The above results in Fig.4(a) &4(b) indicate that there is a gradual decrease of surface roughness with the increase in the cutting velocity from 70 m/min to 162 m/min for all the weight percentages of Zinc Ferrite and copper ferrite nanoparticles added to SAE50 oil separately. The surface roughness is observed minimum for 0.4wt% of Zinc Ferrite and copper ferrite nanoparticles in SAE 50 oil for all the cutting velocities considered for the investigation.

V.CONCLUSION

1. There is increase in Main Cutting Force with the increase in feed rate or cutting velocity.
2. The cutting forces and surface finish of the material is greatly influenced by weight percentage of zinc ferrite and copper ferrite nanoparticles in addition to the cutting parameters.
3. All the cutting forces are minimum at 0.4% of the zinc ferrite and copper ferrite nano- particulate lubricating oils.
4. The surface finish has been observed better when the depth of cut is low (0.25 mm).
5. Surface finish has been observed better with 0.4% weight percentage of copper ferrite nanoparticles added to SAE50 base oil.
6. 0.4 wt %, copper ferrite nanoparticles added to SAE50 base oil shows better lubricating properties as compared to zinc ferrite added to SAE50 base oil as lubricant.

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