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Experimental Investigation on the Application of Zinc Ferrite Added Oil based Nano Fluids and the Cutting Parameters in Turning Operations with Minimum Quantity Lubrication

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***Abstract*:- Turning is one of the basic machining processes for metal cutting. The main problem associated with any metal cutting operation is introduction of undesirable elevated temperature at the cutting zone. Much advancement has been made in this aspect with regards to the lubricant used. Zinc Ferrite nano particles used as lubricants in machining has been a subject of research. The present investigation deals with the use of Zinc Ferrite nano particles in the base oil as a lubricant and as an alternative to the cutting fluids to reduce friction and thereby improve the surface finish of the final product. It deals with the investigation of the influence of Zinc Ferrite nano particle weight percentage in base oil with regard to the variations in tool temperature and surface roughness.**

Key words:- Turning, Zinc Ferrite nano particle, Minimum Quantity Lubrication, Temperature, Surface finish

INTRODUCTION

Machining is a very common and versatile manufacturing process. Turning involves rotation of the work piece while the cutting tool moves in a linear motion. During machining, friction between the tool and work piece gives rise to high temperatures. Due to the plastic deformation of work material, friction at tool-tip interface and friction between the clearance face of the tool and work piece adversely affect the quality of the component produced. In order to improve the machining performance, the cutting zone must be provided cooling and lubrication by cutting fluid.

In general, in the process of machining, metal working fluids act as lubricants. Environmental pollution, dermatitis to operator, soil contamination during disposal and water pollution are the adverse effects of application of conventional cutting fluids. Now-a-days, there is a large-scale evolution of the use of Metal Working Fluids (MWFs) in machining. We find a lot of technological advancements in the development and use of MWF's in machining. Industries are in search of reducing the amount of lubricant used in machining operation because of high percentage of fluid costs in the overall manufacturing costs, hazard to human health and environmental pollution. To overcome these challenges, various alternatives to minimize or avoid the use of cutting fluids are currently being explored by scientists. Minimum Quantity Lubrication (MQL) is the best solution for these problems in an efficient manner.

MQL is the process of applying minute amount of cutting fluid directly to the cutting tool/work piece interface instead of using traditional flood cooling. MQL system uses limited amount of coolant applied either as mist or by mixing coolant with pressurized air or in the forma of drops. Experimental investigations by researchers reveal that MQL shows efficient results in the use of vegetable oil on parameters like tool wear, surface roughness and cutting temperature.

LITERATURE SURVEY

Dhar et.al. [1] conducted experiments to study the influence of Minimum Quantity of Lubrication (MQL) on cutting temperature, chip And dimensional accuracy in turning AISI-1040 steel and concluded that, a mixture of air and soluble oil applied as MQL has been proved to be better comparing with flooding application of soluble oil as cutting fluid.

Krishna et.al. [2] conducted experiments to investigate the performance of nano boric acid suspensions in the coconut oil and SAE-40 oil during turning of AISI 1040 steel. The effect of nano solid suspensions in lubricant is studied in terms of surface finish, tool wear and cutting tool temperatures at variation of cutting parameters. The low temperatures were observed with coconut oil than SAE oil under similar conditions. The tool temperatures were most affected by feed rate than other cutting parameters. surface finish is improved with coconut oil than with SAE oil. They also concluded that flank wear, surface roughness and tool temperatures were minimum with addition of nano particle suspensions in cutting oil than with pure coconut and SAE oil.

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Suresh et. al. [3] investigated the applicability of solid lubricant in turning AISI 1040 steel using coated carbide inserts. Surface roughness and chip thickness ratio were reduced in solid lubricant assisted machining process compared to wet machining in all the test conditions.

The investigations made by Sasidhara, Y.M. and Jayaram, S.R.[4] revealed that the use of cutting fluids for heat dissipation is a common practice but is not advisable in terms of cost, environmental concerns, etc. The experiments conducted by Cakir, O et. al. [5] showed that the use of cutting fluids cannot be entirely eliminated; but can be substituted by finding out alternate means and by using bio-degradable fluids.

Satheesh Kumar, B. et. al.[6] conducted experiments and compared the performance of Vegetable oil based cutting Fluids such as coconut, canola and sesame based cutting fluids each having 5%, 10% and 15% of Extreme Pressure additives during turning of AISI 1040 steel. The influence of cutting oil was expressed in terms of cutting forces, cutting tool temperature, tool flank wear and surface roughness.

R.F.Avila, A.M Abrao [7] 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 done using emulsion without mineral oil gave better tool life when compared to dry cutting.

Electrostatic solid lubrication system was developed to supply constant and defined amount of solid lubricant mixture to the drilling zone [8]. SAE 40 oil was chosen as the mixing medium with graphite solid lubricant and observed improvement in thrust force, tool wear, chip thickness, hole diameter and surface finish of machined work piece in drilling of AISI 4340 steel.

Similarly, 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. [9] 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.

In recent years, magnetic properties of many antiferromagnetic oxides, such as NiO [10, 11], MnO [12], CoO [13] and hematite [14,15] were experimentally studied.

Some of the common solid lubricants are graphite, molybdenum disulphide, tungsten disulphide and calcium fluoride which belong to a special class of materials known as lamellar solids [16], [17].

About present work

The present work is to experimentally investigate the effect of Zinc Ferrite nano particles along with SAE40 oil used as cutting fluid applied under MQL technique in turning AISI 1040 steel by carbide tool inserts. The influence of the weight percentage of nano particle mixed with SAE40 oil has been studied at different cutting parameters of machining. The resulting performance was evaluated in terms of main cutting force, tool tip temperature and surface finish.

Methodology

The performance of any machining operation is affected by the method of application of coolant and type of lubrication. In this study experiments are conducted to investigate the influence of Zinc Ferrite nano particles along with SAE 40 oil as lubricant by conducting turning tests. The tests were conducted on AISI 1040 steel using uncoated carbide inserts. Experiments were conducted to determine optimal weight percentage of Zinc Ferrite nano particles in SAE 40 oil. The different machining conditions considered are cutting velocity (70 m/min), depth of cut (0.25 mm) and feed rate (0.14 mm/rev). The sample weight percentage considered as 0.1% 0.2%, 0..4%, 0.6% and 0.8% in 100 ml of SAE40 oil. Experiments were conducted under MQL conditions. Various input parameters selected for experimentation are presented in Table 1.

TABLE 1: SPECIFICATION OF EQUIPMENT USED

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

The cutting forces were measured using a calibrated strain gauge dynamometer. The temperature is sensed by an embedded thermo couple which is placed at the bottom of the tool inserted in the tool holder as shown in Fig. 1.

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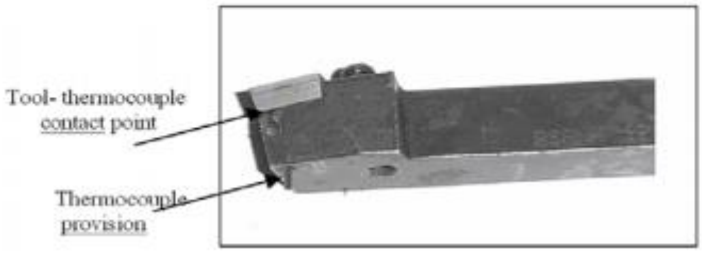

Fig 1: Tool holder showing the provision for thermo couple

The temperature measured by the thermocouple is only a representative value for the purpose of comparison as this does not measure the cutting zone temperature. For measuring average surface roughness, a calibrated surface roughness tester is employed.

At first a set of preliminary tests were conducted to determine the best lubricant flow using the principle of MQL. Flow rate of 20 ml/min of the lubricant is adjusted onto the targeted area.

The experimental set up consists of the lubricant providing a reservoir attached with a stirrer. Initially, SAE 40 oil along with Zinc Ferrite particles were thoroughly mixed in a sonicator and poured into the reservoir. The stirrer was switched on when machining was carried out to avoid agglomeration of the solid particles in the carrying medium (Fig 2).

Fig 2: Experimental setup

RESULTS AND DISCUSSION

Initial experimentation was conducted by considering machining conditions with cutting velocity 70 m/min, depth of cut 0.25, feed rate 0.14 mm/rev.

First, the experiments were conducted in dry machining and machining with pure SAE 40 oil supplied at 20ml/minute and corresponding cutting forces, surface roughness and temperature were recorded. The following Table -2 shows the results of dry and wet machining with pure SAE 40 as cutting fluids.

Table-2: Results of dry & wet machining

Cutting parameter	Dry Machining	SAE40
Temperature (ºC)	150	137
Cutting Force (N)	119	98
Surface Finish (µ)	6.4	6

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The experiments were repeated with SAE40 oil with different weight percentages of Zinc Ferrite nano particles of 0.1%, 0.2%, 0.4%, 0.6%, 0.8% in 100ml of SAE 40 oil.

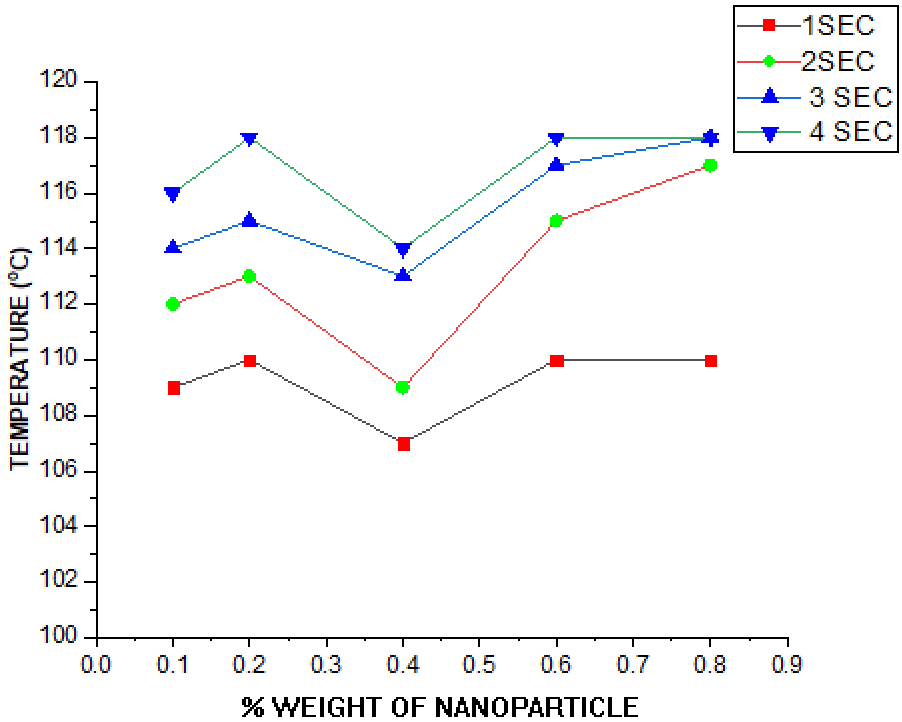

Fig 3: Variations of tool temperature w.r.t. % weight of nano particles

As observed from Fig. 3, as the weight percentage of the nano lubricant in the carrying medium is increased, temperature is at first increased from 0.1 to 0.2%; and in between 0.6% and 0.8% of nano lubricant in the carrying medium, the increase in the measured value stabilizes and so there is no increase in the temperature. At 0.4%, temperature is observed minimum.

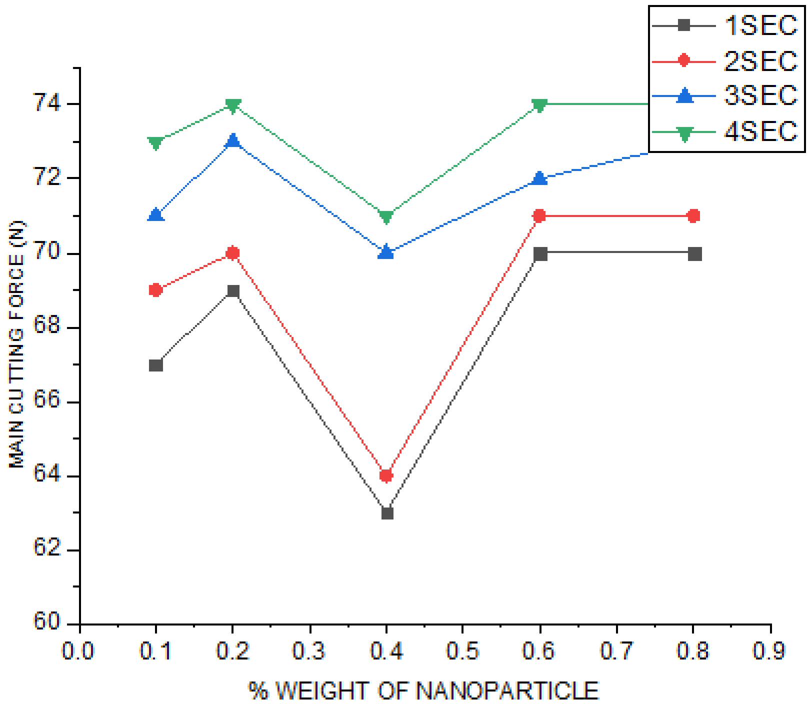

Fig 4: Variation of main cutting force w.r.t. %weight of nanoparticle.

As shown in fig 4, main cutting force is also at first increased and nearly stabilized in between 0.6 to 0.8% and at 0.4%, the main cutting force is observed minimum.

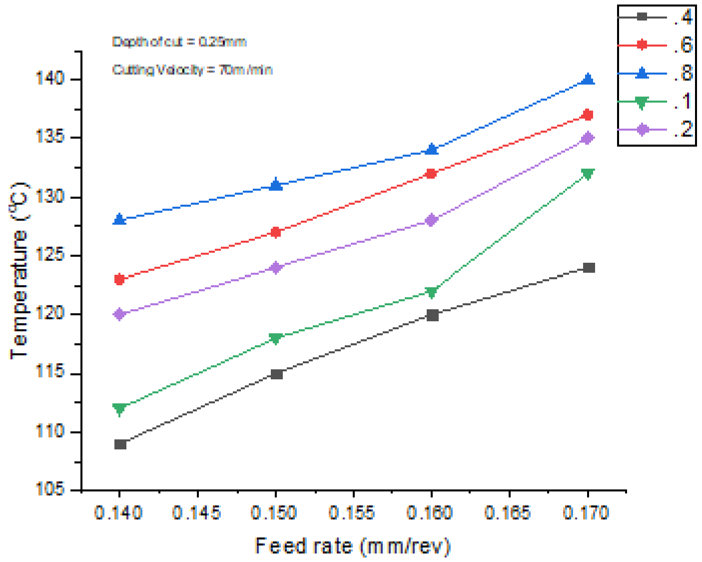

Fig.5(a)

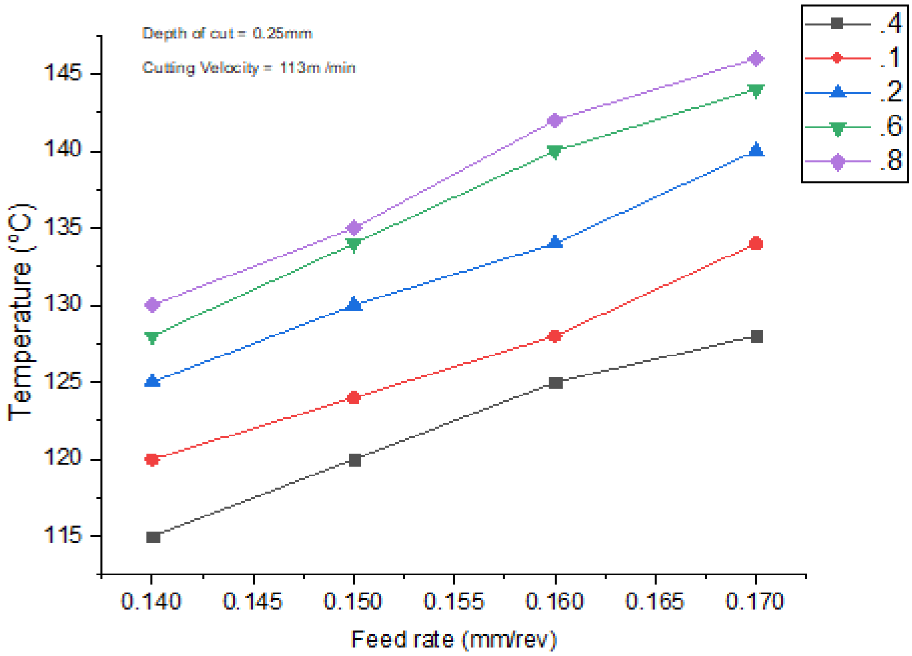

Fig 5(b)

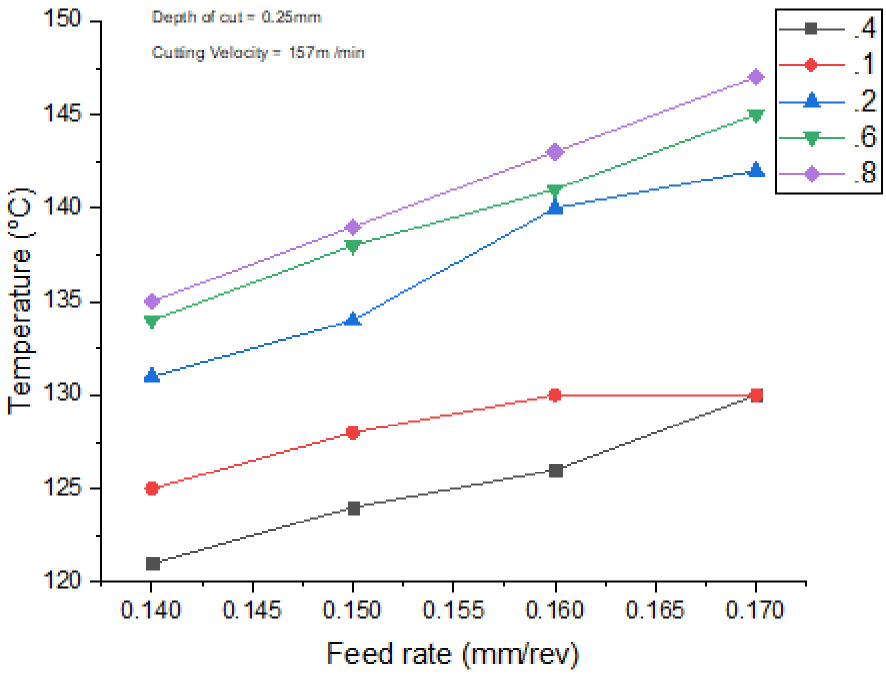

Fig 5(c)

Figs. 5(a), 5(b), 5(c): Variation of tool temperature with respect to feed rate and cutting velocity

Figs. 5(a), 5(b), 5(c) show the variation of tool temperature with respect to tool feed rate, velocity at constant depth of cut, when the cutting fluid of different weight percentages was supplied of 0.1% , 0.2%, 0.4%,0.6%, 0.8%.

The tool tip temperature is increased with the increase of anyone of the following parameters – cutting velocity or feed rate.

The temperature rise is minimized by the addition of nano particles of different weights.

At 0.4% nano particle weight, temperature is less in all the cases.

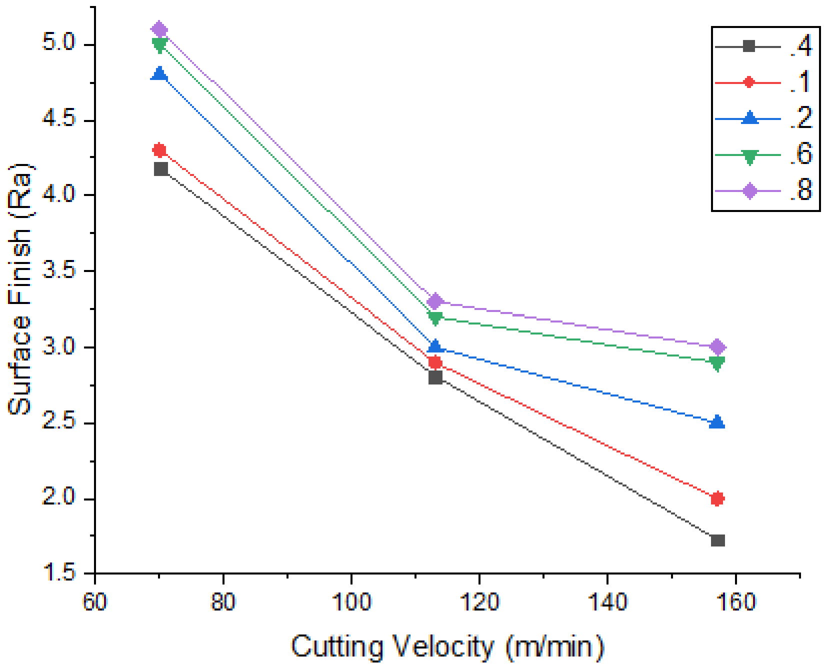

Fig 6: Variation of surface finish with respect to cutting velocity

The above Fig. 6 shows the variation of surfaces finish with respect to cutting velocity at constant feed rate and depth of cut. The horizontal axis is represented with cutting velocity and vertical axis with the average values of surface roughness of the machined surface. It is concluded from the plots that the good surface quality can be obtained with Zinc Ferrite nano particle cutting fluid; and at 0.4% weight of Zinc ferrite, shows the best surface finish.

CONCLUSION

1. The study indicates that the cutting tool temperature and surface finish are greatly influenced by weight percentage of Zinc Ferrite nano particles in addition to the cutting parameters
2. The temperature at the tool tip is increased by increasing anyone or two cutting parameters such as cutting speed, feed rate and depth of cut with keeping other parameters as constant
3. The cutting temperature and surface roughness is minimum at 0.4 weight percentage of Zinc Ferrite nano particle
4. The surface roughness of machined surface is also decreased at 0.4% weight of Zinc Ferrite nano particle.
5. The surface finish is improved by increasing the cutting velocity at constant feed rate and depth of cut.

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