

Selection and Preparation of Copper Oxide Based Nano Fluid and its Effects on Surface Roughness and Tool Wear During Turning of Inconel 718

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ABSTRACT: Proposed work focuses on optimizing turning process parameters for Inconel 718. Effect of CuO Nano lubricant on surface roughness and tool wear will be studied. Experiment will be performed based upon Taguchi DOE. CNC lathe with minimum quantity lubricant discharge setup is used to perform experiments. Surface roughness and tool wear will be measured. Comparison of experimental results for CuO based Nano lubricant with flood cooling and MQL –without additive will be done. Surface roughness and tool wear will be optimized from experimental results. Comparative study for three different environments like machining with Nano lubrication, MQL-without additive and flood cooling will be beneficial to select suitable environment during turning of Inconel 718.

KEYWORDS: Nano Fluid, CuO based, Inconel 718, MQL, Soya bean Oil, and Turning.

1. INTRODUCTION

Conventional machining is one of the most important metal removal method. Turning operation is very important material removal process in modern industries. At least one fifth of all applications in metal cutting are turning operations. Inconel 718, a nickel based super alloy is an extensively used alloy in the aerospace industry, marine industry, steam turbine, power plants, nuclear reactors, pumps and aircraft engine. It is difficult to cut material due to its properties like low thermal conductivity, work hardening etc. and retains its strength at high temperatures. Due to low machinability of this material, worked surface and subsurface are easily affected during machining operations. Close tolerance and outstanding surface finish become critical for their application. Therefore, surface finish plays a vital role in machining Inconel 718. MQL technique employs a mixture of high-pressure air (3–7 bar) and small amount of lubricating fluid (5–500 ml/h), supplying it to the contact region during machining. To improve the lubrication properties of MQL system, application of different nanofluids is an ongoing research area.

II.OBJECTIVES OF WORK

In the light of research issues, literature review discussed above and problem definition the specific research objectives are formulated as below,

1. To find suitable base fluid for CuO to disperse.
2. To select process parameter for experimentation from literature review.
3. To investigate the influence of CuO based nanoparticles on surface roughness during turning of Inconel 718 with MQL.
4. To investigate the influence of CuO based nanoparticles on tool wear during turning of Inconel 718 with MQL.

III. METHODOLOGY

1. Selection of base fluid and preparation.
2. Selection of process parameter from extensive literature review.
3. Selection of orthogonal array from Taguchi method.
4. Experimentation will be carried out as per selected array on CNC machine with MQL set up.
5. Measurement of surface roughness and tool wear,

III. INTERPRETATION OF RESULT AND CONCLUSION

3.1 Selection of base fluid

A lubricant is a substance used to facilitate relative motion of solid bodies by minimizing friction and wear between interacting surfaces. In addition to the primary purpose of reducing friction and wear, lubricating oils are also required to carry out a range of other functions, including removal of heat. Corrosion prevention and transfer of power, providing a liquid seal at moving contacts and removal of wear particles. Metal working fluids (MWFs). Otherwise known as cutting fluids come under lubricants which are extensively used in machining operations.

As base fluid plays important role in machining processes to prevent tool from overheating. To keep the work material at low temperature. To reduce the power consumption. To provide good surface finish. To wash away the chips, to prevent the corrosion of work. For this purpose of selection of effective base fluid, we have studied some research papers and the results obtained from those research papers are mentioned below.

Vegetable Oil (Soya bean oil):

Traditionally cutting fluids are used to carry away the heat and reduce the friction produced in machining. In a majority of the applications, water miscible cutting fluids are used. Conventional cutting fluids suffer from many limitations such as environmental and disposal issues. Hence, the Concept of MQL is becoming significant. Small quantities of the fluid are supplied to the cutting Zone in order to cool and lubricate the working zone. The fluid may be supplied in the form of neat oil or as a water miscible cutting fluid. As a further step towards sustainable manufacturing. The ingredients in the cutting fluids are being replaced with vegetable alternatives. Because of their superior properties, vegetable-based cutting fluids exhibit better performance compared to the mineral oils. Inclusion of nanoparticles in both mineral and vegetable oils to enhance the performance is tried by many researchers. But the cost of the particles is many times prohibitive. Future research may be directed at improving the performance of the fluids through alternate measures.

3.2 Selection and Mixing of nano particles in oil:

In this experiment we choose Copper oxide (CuO) Nano particles. The reason behind the selection of CuO nanoparticles is that Copper has the best thermal conductivity among all the metals. Copper can carry more heat than any other metal hence, using this CuO in proportion can give more better results when used in correct proportion.

The mixing of copper oxide (CuO) particles in oil was carried out in two steps as follows

1. Mixing with the use of magnetic stirrer.
2. Use of ultrasonic bath sonicator.

3.2.1 Magnetic stirrer:

Specifications:

1. Model – 1 ML Q19
2. Stirring capacity – 1ML
3. External dimensions- 150 x 220 x 150

Mixing process:

1. First step was to add copper oxide nano particles in oil with proportion to it.
2. In our case we took 1%, 2%, 3% i.e. 1g, 2g, 3g of CuO nanoparticles respectively and mixed it in oil.
3. For each sample 8 hours of time was required for mixing.

3.2.2 Ultra sonic bath sonicator:

When the solution was prepared with magnetic stirring then the same solution was carried further to mix more efficiently in ultra-sonic bath sonicator.

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultrasonication or ultra-sonication.

Sonication has numerous effects, both chemical and physical. The chemical effects of ultrasound are concerned with understanding the effect of sonic waves on chemical systems, this is called sonochemistry. The chemical effects of ultrasound do not come from a direct interaction with molecular species. Studies have shown that no direct coupling of the acoustic field with chemical species on a molecular level can account for sonochemistry or sonoluminescence. Instead, in



sonochemistry the sound waves migrate through a medium, inducing pressure variations and cavitation's that grow and collapse, transforming the sound waves into mechanical energy.

3.3 Design of Experiment using Taguchi Approach

The Taguchi method was developed by Genichi Taguchi. He developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations, This allows for the collection of the necessary data to determine which factors most affect the product quality with a minimum amount of experimentation, thus saving time and resources, The Taguchi method is best used when there is an intermediate number of variables. Few interactions between variables, and when only a few variables contribute significantly.

The first step in Taguchi's parameter design is selecting the proper orthogonal array (OA) according to the controllable factors (parameters). Then, experiments are run according to the OA set earlier and the experimental data are analysed to identify the optimum condition. Once the optimum conditions are identified. Then confirmation runs are conducted with the identified optimum levels of all the parameters.

3.3.1 Designing an experiment:

1. The design of an experiment involves the following steps
2. Selection of independent variables
3. Selection of number of level settings for each independent variable
4. Selection of orthogonal array
5. Assigning the independent variables to each column
6. Conducting the experiments
7. Analysing the data

3.3.2 Parameters for Experiment:

In current experimentation four process parameters are selected as control factors. The remaining process parameters kept as constant. Controlled and constant parameters are given in table 3.1 and table 3.2.

Table 3.1: Controlled parameters.

Sr. No.	Controlled parameters
1.	Cutting speed (m/min)
2.	Wt. % of CuO
3.	Flow Rate (ml/hr.)

Table 3.2: Constant parameters.

Sr. No.	Constant parameters	
1.	Cutting fluid	CuO Nano lubricant
2.	Work material	Inconel 718
3.	Tool insert	TiAlN coated carbide
4.	Depth of cut	1 mm



3.3.3 Levels of Controlled Parameters:

In industry, selection of levels of process parameters is largely depending on production engineer’s experience. So, number of researchers focused their study to find relationship between process parameters and performance characteristics. In present experimentation, process parameters levels are selected with help of self-initial experiments, literature review and experience of production engineer. From summary of literature review, we observed that speed, tool grade, wt. % of nanoparticles plays an important role on performance characteristics hence here we select cutting speed, flow rate, wt.% of nanoparticles as a process parameter. For present experimentation, we use L9 design of experiment. There are three process parameters, three process parameters have three levels combination as shown in Table 4.3.

Table 3.3: Parametric combinations in coded form

Sr. No.	FLOW RATE	CUTTING SPEED	Wt. %
1	R1	S1	W1
2	R2	S2	W2
3	R3	S3	W3
4	R1	S1	W2
5	R2	S2	W3
6	R3	S3	W1
7	R1	S1	W3
8	R2	S2	W1
9	R3	S3	W2

Where,

R – Flow rate

S – Cutting speed

W – Weight percentage of a nano particles.

3.4 Selection of Workpiece:

Workpiece material selected for the experimentation is Inconel 718, round bar.

3.5 Selection of Tool Insert:

For the current experimental work, for turning of the Inconel 718, the coated carbide tool insert is selected. The details of the tool are given below.

Maker: TaeguTec

Designation: TNMG 160408 MT TT 5080

Cutting speed – max. 30 to 80 m/min

Feed – 0.05 to 0.4 mm/rev.

Depth of cut – 0.2 to 3 mm

3.6 CNC Machine Used for Experimentation and its specifications:

Machine used for experimentation is made up of MTAB control system and its other specification are given below, Table.3.4 CNC machine specification.

Machine Name :	CNC Turning Centre
Manufacturer :	Laxmi Machine Work Ltd.
Technical Specifications	
Chuck Diameter :	210 mm max
Maximum Turning Centre :	320 mm max
Bar Capacity :	40 mm max
Maximum Machining Diameter :	160 mm
Spindle Speed Range :	3000-3500 rpm
Feed Range in mm/min :	1 to 2000
Turret- No. of Station :	8 nos.

3.7 MQL setup:



Figure 3.4: MQL Setup

The figure of MQL is shown above in fig 3.4. It consists of two inlet ports for oil and compressed air. There is a space where both oil and air gets mixed. Due to pressure the mixture of oil and compressed air come out from outlet port. The flow can be controlled by rotation of nozzle tip. The clockwise rotation increases the flow whereas anticlock wise rotation decrease the flow.

3.8 Assessment of experiments carried out on work piece

3.8.1. Surface Roughness Measurements:

Surface roughness was measured using the Mitutoyo surface roughness tester model name sj-210 as shown in fig. The arithmetic average roughness value is measured. The surfaces finish value of the machined Inconel 718 bar was measured after completion of one machining.

Specifications:

- Traverse Speed: 0.5 mm/sec.
- Cut off values: 5mm
- Display: LCD.



Figure 3.4: Mitutoyo Surface Roughness Tester

3.8.2 Tool Wear Measurement:

Tool wear rate is measured using Mitutoyo tool maker’s microscope as shown in fig., Least Count of this tool maker’s microscope is 0.005 mm.

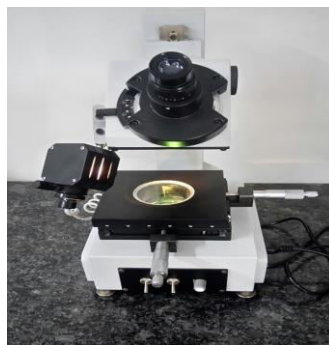


Figure 3.5: Mitutoyo Tool Maker’s Microscope

IV. EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Determination of significant process parameters for surface roughness by ANOVA method: -

Surface roughness measured with help of Mitutoyo surface roughness (μm) tester on external face of specimen having a stroke length $0.25 \times 5 \mu\text{m}$. S/N ratio for average of two repetitions for surface roughness is given in table 4.1

Table 4.1: Experimental results of surface roughness in μm

Exp No	FLOW RATE	CUTTING SPEED	Wt. %	ROUGHNESS
1	40	120	1	0.617
2	40	140	2	0.600
3	40	160	3	0.551
4	50	120	2	0.491
5	50	140	3	0.417
6	50	160	1	0.395
7	60	120	3	0.425
8	60	140	1	0.400
9	60	160	2	0.395

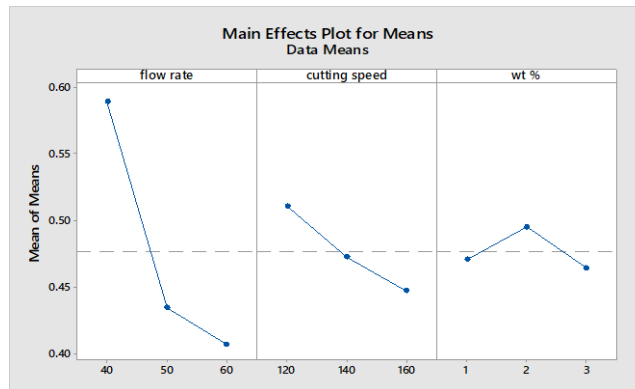


Chart - 4.1: Main effect plot for means.

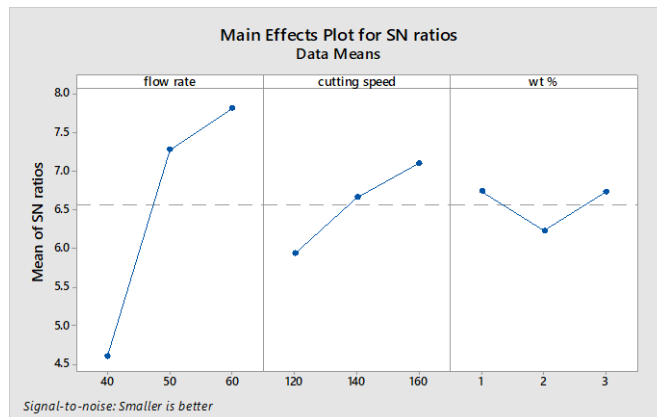


Chart-4.2: Main effect plot of S/N ratio for Ra

In main effect plot of S/N ratio for surface roughness, X-Axis indicates different levels of process parameters and Y-Axis shows average of S/N ratio. It can be observed from Figure 4.1 that surface roughness start decreases as flow rate increases, as cutting speed increases surface roughness start increasing. With increase in feed surface roughness start increasing.

Table 4.2: Analysis of variance surface roughness

Source	DF	Adj.SS	Adj.MS	F value	P value	% contribution
Flow rate	1	0.6242	0.062422	9.89	0.008	48.71
Cutting	2	0.1168	0.056839	9.01	0.004	44.38
Wt %	2	0.01768	0.008839	1.40	0.284	6.89
Error	12	0.07573	0.006311			
Total	17	0.26951				

Table-4.3: Response Table for S/N Ratios for surface roughness

Level	Flow rate	Cutting speed	Wt. %
1	0.5893	0.5110	0.4707
2	0.4343	0.4723	0.4953
3	0.4067	0.4470	0.4643
Delta	0.1827	0.0640	0.0310
Rank	1	2	3



4.2 Determination of significant process parameters for tool wear by anova method.

Table 4.4: Experimental results of tool wear in μm

Expt. No	FLOW RATE	CUTTING SPEED	Wt. %	TOOL WEAR
1	40	120	1	0.10
2	40	140	2	0.09
3	40	160	3	0.09
4	50	120	2	0.08
5	50	140	3	0.03
6	50	160	1	0.02
7	60	120	3	0.04
8	60	140	1	0.02
9	60	160	2	0.01

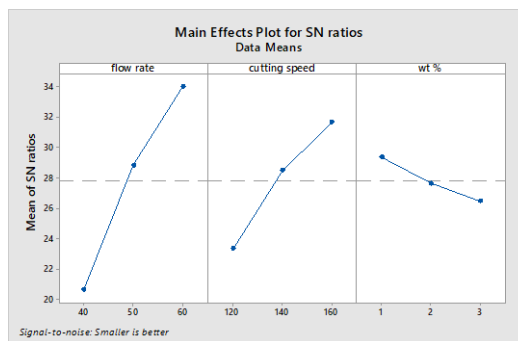


Chart - 4.3: Main effect plot of S/N ratio for tool wear

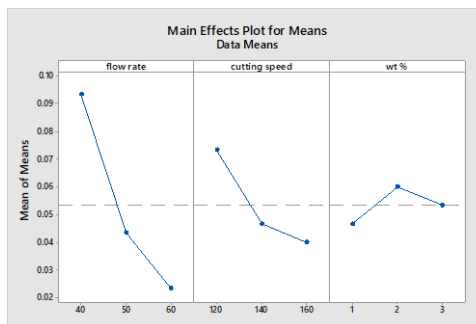


Chart - 4.4: Main effect plot for means for tool wear

In main effect plot of S/N ratio for tool war, X-Axis indicates different levels of process parameters and Y-Axis shows average of S/N ratio. It can be observed from figure4.4 at minimum flow rate and wt. % tool wear in minimum, also at minimum cutting speed tool wear is minimum. As feed rate increases tool wear increases.



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Source	DF	Adj.SS	Adj.MS	F value	P value	% contribution
Flow rate	2	0.007800	0.003900	16.71	0.056	78.52
Cutting	2	0.001867	0.000933	4.00	0.200	18.79
Wt %	2	0.000267	0.000133	0.57	0.636	2.67
Error	2	0.000467	0.000233			
Total	8	0.010400				

Chart - 4.5: Analysis of variance for tool wear

Table 4.6: Response Table for S/N Ratios for tool wear Smaller is better

Level	Flow rate	Cutting speed	Wt. %
1	0.09333	0.07333	0.04667
2	0.04333	0.04667	0.06000
3	0.02333	0.04000	0.05333
Delta	0.07000	0.03333	0.01333
Rank	1	2	3

4.3 Prediction of optimal value of surface roughness by using following regression equation.

Once the optimal level of the geometry parameters is identified, the final step is to predict and validate the improvement of the performance measures using the optimal level, i.e. for surface roughness S3-F3-W3. The purpose of the confirmation experiment is to verify the conclusions drawn during the analysis phase.

The response was correlated with the factors using the first order polynomial. The relationship between surface roughness and process parameters as shown in table below

Table 4.7: Optimal values

Term	Coefficient
Constant	1.164
Flow rate	-0.00913
Cutting speed	-0.001600
Wt.%	0.0032

Regression Equation for surface roughness

$$1. T1 = 1.164 - 0.00913 \text{ flow rate} - 0.001600 \text{ cutting speed} - 0.0032 \text{ wt. \%}$$

For this model R^2 value = 85.13%, R^2 (adj) = 76.12% this indicate that the model is desirable and 57.88 %variability is explained by the model after considering significant parameters.

$$\begin{aligned} \text{Ra Value} &= 1.164 - 0.00913*(60) - 0.001600(160) - 0.0032 *(3) \\ &= 0.3506\mu\text{m} \end{aligned}$$

4.4 Prediction of optimal value of tool wear by using following regression equation

Once the optimal level of the geometry parameters is identified, the final step is to predict and validate the improvement of the performance measures using the optimal level, i.e. for tool wear S3-F3-W3. The purpose of the confirmation experiment is to verify the conclusions drawn during the analysis phase.

The response was correlated with the factors using the first order polynomial. The relationship between tool wear and process parameters as shown in table below

Regression Equation

$$\text{Tool wear} = 0.3383 - 0.003500 \text{ flow rate} + 0.00333 \text{ wt. \%} - 0.000833 \text{ cutting speed}$$

For this model $R^2 = 87.34\%$, $R^2(\text{adj}) = 79.74\%$ this indicate that the model is desirable and 61.86 % variability is explained by the model after considering significant parameters.

$$\begin{aligned} \text{Tool wear} &= 0.3383 - 0.003500 * 60 + 0.00333 * 3 - 0.000833 * 160 \\ &= 0.00501 \end{aligned}$$

V. CONCLUSIONS

Through the conducted experiment we came to know that when flow rate increases surface roughness value (ra) decreases, similarly when cutting speed increases then surface roughness value (ra) decrease. In case of tool wear, when flow rate increase tool wear decrease, similarly when cutting speed increases tool wear decrease.

Weight percent of copper oxide in nano fluid plays another major role on tool wear and surface roughness values. Weight percentage of copper oxide should be in right quantity neither more nor less to achieve better results.

It is been observed that using 2% of CuO based nano fluid has better results than that of 1% and 3%.

Gradually conventional use of cutting fluid litres per hour is reduced to mille litres per hour so it's also very economical to use.

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