Optimization Of Process Parameters For Material Removal Rate Under Flooded And MQL Conditions

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ABSTRACT

Ecological and environmental aspects of coolants are to be considered in machining. The use of Biodegradable oil can be an alternative source of coolants. This paper reports the experimental results of using coconut oil (vegetable oil) with MQL as an alternative cutting fluid while performing Turning operations on a Centre lathe machine using Carbide cutting tools and the Results of MQL and Flooded conditions were compared. The coolants prepared with the composition of 40%Coconut oil +40% oleic acid+20% Triethanol Amine are used for machining. Experiments were performed on a solid cylindrical workpeice of Alloy steel(EN353). Experimental result shows that during the turning operation the vegetable oil showed great cooling effect and lubrication under MQL and Flooded conditions. As it is also concluded that Vegetable oil a bio degradable oil resulted in less environmental effect compared to synthetic oils.

Keyword: - *Taguchi Method, Vegetable Oil, EN-353 Alloy, Turning, Material Removal Rate (MRR), Signal to noise (S/N) ratio etc.*

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1. INTRODUCTION:

Machining experiences high temperatures due to friction between the tool and work piece, thus influencing the workpiece dimensional accuracy and surface quality. Machining temperatures can be controlled by reducing the friction between tool–work-piece and tool–chip interface with the help of effective lubrication. Cutting fluids are the conventional choice to act as both lubricants and coolants. But, their application has several adverse effects such as environmental pollution, dermatitis to operators, water pollution and soil contamination during disposal [1,2]. Further, the cutting fluids also incur a major portion of the total manufacturing cost. All these factors prompted investigations into the use of biodegradable coolants or coolant free machining. Hence, as an alternative to cutting fluids, researchers experimented with dry machining, coated tools, cryogenic cooling, minimum quantity lubrication (MQL) and solid lubricants. Dry machining, has been reported to be capable of eliminating cutting fluids with the advancement of the cutting tool materials [3]. Dry machining requires less power and produces smoother surface than wet machining at specified cutting conditions [4].

In tribological applications of hard protective coatings the toughness is as important as their hardness, since both properties shave great influence on the wear resistance of coated tools [5]. Ita kura etal. [6] conducted dry turning experiments to identify the tool wear mechanisms with coated cemented carbide tool while machining Inconel 718.During continuous cutting almost no rake wear but only flank wear appeared. The primary function of a cutting fluid in wet machining operations is to cool, to lubricate, and to remove the chips. Emulsions or straight oils are generally used depending on the manufacturing operation and machining task involved. Straight oil is a cutting fluid that is composed of mineral oil or vegetable oil and is mainly used as a lubricant. Research by Rao DN, Srikant RR (2006) showed straight oil is not intended to be mixed with water. Emulsions possess excellent heat transfer characteristics because of their high water content. Straight oils excel when a high degree of lubricity is required. Both media guarantee efficient chip transport, when compressed air is used instead of a cooling lubricant, the lubrication benefit of the fluid is lost. The coolant effect is much less pronounced than with water or oil. Water and oil are also superior to air in terms of chip transport characteristics. In wet machining, machining with cutting fluids causes environment, water source pollution and soil become polluted during disposal of the cutting fluid. In MQL operations, the media used is generally straight oil, but some applications have also utilized an emulsion or water as showed by M. N. Morgan (2012). These fluid media is fed to the tool and work piece interface in tiny quantities. This is done with or without the assistance of a transport medium, e.g., air. In many machining operations, minimum quantity cooling lubrication (MQL) is the key to successful dry machining. Nanofluids are engineered colloidal suspensions of Nanoparticles in a base fluid. It has been found by M. M. A. Khan (2009), that Nanofluids have much higher and strongly temperature dependent thermal conductivity at very low particle concentration, which is considered to be a key parameter for enhanced performance for many of the applications. Vegetable oil(Coconut oil) Nanoparticles have been analysed by Pil-Ho Lee (2012) and it was found to be most suitable as it increases wettability, reduces cutting forces, and shows enhanced tribological effects (like ball / roller effect) along with minimum toxic nature.

2. EXPERIMENTAL SETUP AND DESIGN:

2.1. Selection of Work Material:

The work piece material will EN353 steel in the form of round bars of 27 mm diameter and length of 120 mm axial cutting length. The composition of material is

Fig. No. 1: CNC Lathe

Fig. No. 2: EN353 Alloy Steel

Fig. No.3. Cutting tool Inserts

Fig. No.4 MQL setup

EN353 is widely used for Machining components in various industries. This material has significant application in automotive industry. Typical applications of this material are crown wheel, crown pinion, bevel pinion,bevel wheel, timing gears, king pin, pinion shaft, differential turning etc

2.2. Selection of Insert:

The cutting inserts used for machining are CNMG carbide tools of KORLEY Company, which are Gold coated, silver coated and uncoated Carbide tools as shown in the fig.no.3.

2.3. Selection of Lubricant:

Selection of cutting fluid is important in order to maintain better tool life, less cutting forces, lower power consumption, high machining accuracy and better surface integrity etc. Here Vegetable Oil {coconut oil}, is used as cutting fluid in MQL and flooded conditions. Coconut oil is an environmentally acceptable vegetables oil based lubricant. Coconut oil will yield the lowest net manufacturing costs of any fluid as found by Jung Soo, et al. (2011.)

2.4. Preparation of vegetable oil (coconut oil):

The mixture of vegetable oil (coconut oil), oleic acid and triethanol amine is used as lubricant, from these three chemicals, coconut oil and oleic acid will improve machining parameters. The solvent triethanol amine is used for proper mixing of coconut oil and oleic acid. It can also control the evaporation rate of water in coolant.
Composition of solution as follows:
1 Coconut Oil is taken 40%
2 Oleic Acid is taken 40% and

3 Triethanol Amine is 20%
40% of coconut oil is taken in a beaker and then 20% of triethanol amine is mixed in coconut oil and this mixture is stirred with mechanical stirrer for half an hour and then 40% of Oleic acid is added in the above solution slowly to dissolve or proper mixing and it is stirred for an half an hour to get a homogeneous mixture which is to be dissolve in water in all conditions.

2.5. Experimental Design:

The four control factors speed (A), feed (B), Depth Of Cut(c)and type of tool (D) are selected with three levels and the corresponding orthogonal array L9 (34) is chosen with respect to its degrees of freedom[1] and are tabulated in Table No.1. Steel bars of 28mm diaX120mm length are prepared for conducting the experiment. Using different levels of the process parameters as per the experimental design shown in table no.2, the specimens have been machined in Lathe Machine accordingly, the MRR is measured precisely with the help of MRR Formulla

Table No. 1: Control Factors & Levels for (MQL&Flooded)

Factors /Levels	**Speed (A) (rpm)**	**Feed (B) (mm/min)**	**Depth Of Cut (C) (mm)**	**Type of tools (D)**
1	700	0.2	0.5	uncoated
2	1100	0.5	1.5	Gold
3	1500	0.8	2.5	silver

Table No. 2. Experimental Design with MQL and coolant

EXPERIMENT NO.	**SPEED**	**FEED**	**DEPTH OF CUT**	**TYPE OF tool**
1	700	0.2	0.5	Uncoated
2	700	0.5	1.5	Gold
3	700	0.8	2.5	Silver
4	1100	0.2	1.5	Silver
5	1100	0.5	2.5	Uncoated
6	1100	0.8	0.5	Gold
7	1500	0.2	2.5	Gold
8	1500	0.5	0.5	Silver
9	1500	0.8	1.5	uncoated

Fig. No. 5: Machining of EN353 Alloy Steel in CNC Lathe

3. RESULTS & DISCUSSIONS:

The MRR is measured precisely with the help of MRR Formula under MQL and flooded conditions and the experiments results are tabulated in table no. 3&8 for two trails. For each experiment the corresponding mean and S/N ratio values are also tabulated. Optimization of MRR is carried out using Taguchi methodology. Confirmatory test have also been conducted to validate optimal results.

$$MRR = \frac{1000 \times W_w}{\rho_w \times t} \ \text{mm}^3/\text{min}$$

Table No.3. Experimental Results of MRR (MQL) with the corresponding S/N Ratio's

EXP NO.	MRR (MQL)			S/N RATIO
	TRAIL1	TRAIL2	MEAN	
1	514.65	520.8	517.725	52.37
2	5886.26	5990.1	5938.18	71.79
3	11724.85	11734.2	11729.52	82.08
4	4705.42	4685.3	4695.36	72.03
5	7962.54	7932.2	7947.37	79.13
6	1060.82	1060.88	1060.88	60.51
7	6608.9	6610.5	6609.7	76.4
8	550.05	548.1	549.075	54.79
9	9045.9	9048.1	9047	79.13

Table No 4. Summary of S/N Ratios

Factor	Level 1	Level 2	Level 3
Speed(A)	68.74	**70.55**	70.1
Feed(B)	66.93	**68.57**	73.9
Depth of cut(C)	55.89	74.31	**79.2**
Type of tool(D)	**70.21**	69.56	69.63

From above tableno.4, the speed best level is level 2, feed is level 2, depth of cut is level 3 and type of tool is uncoated. Thus, the optimum conditions chosen under MQL conditions were: **A2-B2-C3-D1**. A confirmation test is performed with the obtained optimum cutting, the MRR is measured and the S/N ratio is calculated for this condition. The conformation test results and the predicted values are tabulated in the table no 6 & 7.

Table No 5: Optimum Set of Control Factors for MRR (MQL)

Factors /Levels	**Speed(RPM) (A)**	**FEED (B) (mm/min)**	**Depth of cut(C) (mm)**	**Type of tool (D)**
Optimum Value	**1100**	**0.5**	**2.5**	**uncoated**

Table No 6. Conformation results

Cutting Temperature			S/N RATIO
1	2	Average	
8013.4	8028.2	8020.8	78.08

Table No 7. Comparison of S/N ratios

η predicted	79.13
η conformation	78.08

Table No.8. Experimental Results of MRR (Flooded) with the corresponding S/N Ratio's

EXP NO.	**MRR (flooded)**			**S/N RATIO**
	TRAIL1	**TRAIL2**	**MEAN**	
1	416.4	415.1	415.75	52.37
2	3889.67	3889.3	3889.48	71.79
3	12711.86	12714.7	12713.28	82.08
4	3998.47	3994.5	3996.48	72.03
5	9055.78	9048.2	9051.9	79.13
6	768.18	752.2	760.19	57.62
7	7278.7	7268.8	7273.75	77.23
8	464.1	462.8	463.45	53.32
9	7425.74	7428.2	7426.97	77.42

Table No 9: Summary of S/N Ratios

Factor	**Level 1**	**Level 2**	**Level 3**
Speed(A)	68.74	**69.59**	69.32
Feed(B)	67.21	68.08	**72.37**
Depth of cut(C)	54.44	73.74	**79.48**
Type of tool(D)	**69.64**	68.88	69.14

From table no. 9 the speed level at level 2, feed at level 3, depth of cut at level 3 and type of tool at level 1 are higher values. Thus, the optimum conditions chosen were: **A2-B3-C3-D1**. A confirmation test is performed with the obtained optimum cutting, the MRR is measured and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 11 & 12.

Table No 10: Optimum Set Of Control Factors for s/n ratio (FLOODED)

Factors /Levels	**Speed(RPM) (A)**	**FEED (B) (mm/min)**	**Depth of cut(C) (mm)**	**Type of tool (D)**
Optimum Value	**1100**	**0.5**	**2.5**	**uncoated**

Table No 11. Conformation results

Cutting Temperature			S/N RATIO
1	2	Average	
14320.1	14021.2	14170.65	83.02

Table No 12. Comparison of S/N ratios

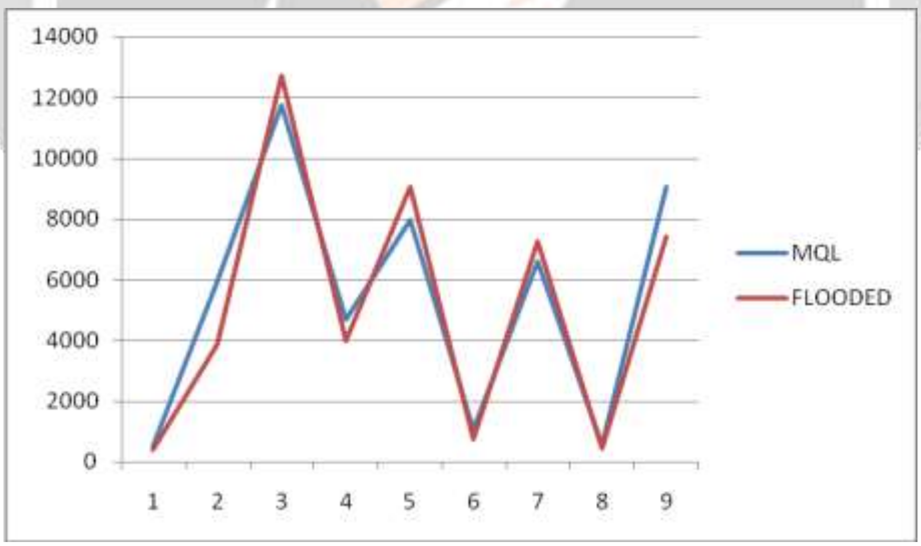
η predicted	83.42
η conformation	83.02

3.1. Effect of Cutting Parameters on Cutting Temperature:

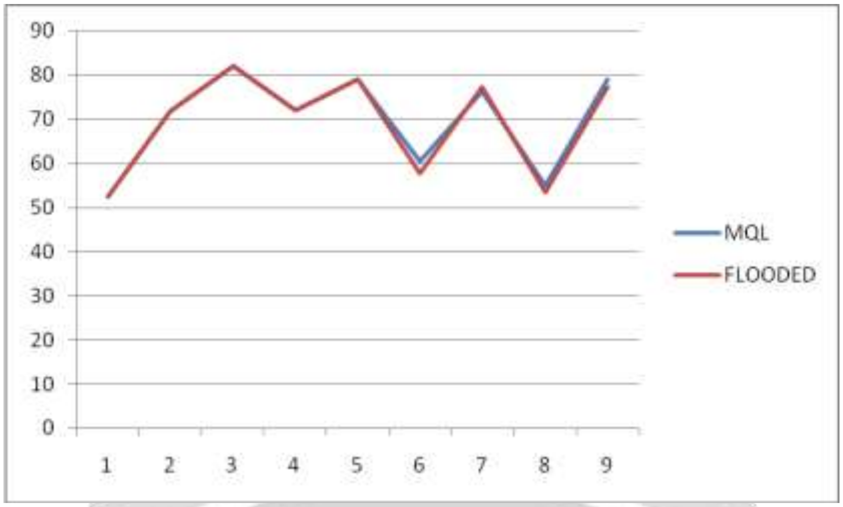
Taguchi's methodology has been successfully implemented to identify the optimum settings for control parameters in order to decrease Cutting temperature of the selected work piece material for their improved performance, after analysis of data from the design of experiments the optimum setting are found. These optimum settings combination is validated by conducting confirmation test, which concluded that the results were within the acceptable limits of the predicted value and can be implemented in the real time application.

3.2. Comparsion of MQL and Flooded Nano fluid:

Comparison of MQL and Flooded MRR values are plotted in graph no.1 where it shows comparatively equal results for both MQL and Flooded conditions. Similarly the S/N ratios are plotted in graph no.2 shows comparatively same results for the same conditions under MQL and Flooded.



Graph No.1: MRR For MQL vs FLOODED



Graph No. 2: S/N RATIO for MQL vs FLOODED

4. CONCLUSIONS:

The objective of the paper is to find out the set of optimum conditions in order to improve MRR, using Taguchi's techniques considering the Turning parameters for the EN 353 Steel Alloy material using vegetable oil. Based on the results of the present experimentation the following conclusions are drawn:

- In the present under MQL condition the optimum speed obtained using Taguchi Robust Design Methodology is 1100 rpm. Similarly the results obtained for feed and depth of cut are 0.5mm/min and 2.5mm respectively. The corresponding Type of tool is uncoated carbide tip for MQL conditions.
- For Flooded conditions the optimum speed obtained using Taguchi Robust Design Methodology is 1100 rpm. Similarly the results obtained for feed and depth of cut are 0.8mm/min and 2.5mm respectively. The corresponding Type of tool is uncoated carbide tip.
- The S/N ratio of predicted value and verification test values are valid when compared with the optimum values under both the cooling technique conditions. It is found that S/N ratio value of verification test is within the limits of the predicted value and the objective of the work is full filled.
- It is also observed that machining of EN 353 Steel Alloy using vegetable oil under MQL and Flooded conditions the results generated are almost same, by which we can conclude that MQL is a better alternate cooling technique than flooded cooling where we can minimize the coolant utilization.
- As it is also concluded that Vegetable oil which is bio degradable oil showed good machining characteristics and resulted in less environmental effect compared to synthetic oils.

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