Experimental Investigation on Effect of Machining Parameters of EN353 Alloy Steel Using Nano Fluids

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ABSTRACT

Almost all machining process produces heat and friction which will potentially damage the cutting tools as well as the machined work piece. To reduce the friction, heat transfer and to remove metal particles away from the cutting zone normally lubricants/cutting fluids are widely used in metal cutting industries during machining operation The objective of the present work is to find out the set of optimum conditions for the selected process parameters, using a nano fluid mixture of Al_2O_3 *and water. Taguchi method is used to determine the optimum cutting parameters viz. cutting speed, feed rate, depth of cut and type of tool at three different levels. The Experiments are carried out using* L_9 (3^4) *orthogonal array and the work material used is EN 353 Alloy Steel. Nano fluids have novel properties that make them potentially useful in heat transfer medium in cutting zone. The Minimum quantity lubrication (MQL) presents itself as a viable alternative for turning with respect to tool wear, heat dissipation, and machined surface quality etc. This study compares the mechanical performance of MQL based Nano fluids and flooded based Nano fluid for the turning operation of EN353. As it was observed that machining 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.*

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

1. INTRODUCTION:

The growing demand for higher productivity, product quality and overall economy in manufacturing by machining, insists high material removal rate and high stability and long life of the cutting tools. But machining with high cutting velocity, feed rate and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature. Such high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the surface integrity of the product by inducing tensile residual stresses, surface and subsurface micro-cracks in addition to rapid oxidation and corrosion. Application of Nano fluid lubrication in cutting has proved to be feasible alternative to cutting fluids, if it can be applied properly. If the friction at the machining zone can be minimized by providing effective lubrication, the heat generated can be reduced to some extent. If a suitable lubricant can be successfully applied in the machining zone, it leads to process improvement. Several studies related to the lubrication properties of Nano fluids are carried out over the past several decades.

2. EXPERIMENTAL SETUP:

2.1. Selection of Work Material:-

The work piece material used is EN353 steel in the form of round bars of 28 mm diameter and length of 120 mm. 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. The gears especially crown wheel and pinion are one of the most stress prone parts of a vehicle, which are made of EN353 steel.

Fig. No. 1: CNC Lathe

Fig. No. 2: EN353 Alloy Steel

Fig. No.3. Cutting tool Inserts

Fig. No. 4 MQL setup

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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 (shown in Fig. 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 Nano fluid, is used as cutting fluid in MQL and Flooded conditions.

2.4. Preparation of Nano Fluids

In the present work alumina (Al_2O_3) Nano particles are mixed with water, as a base fluid used is water, to make Al_2O_3Nanofluid. Five grams of Al_2O_3 Nano particles and directly mix with 100 ml of water as a base fluid.

3. EXPERIMENTAL DESIGN

The four control factors Cutting Speed (A), Feed Rate (B) and Depth Of Cut(C) and type of tool(D) are selected with three levels and the corresponding orthogonal array L_9 (3^4) is chosen and are tabulated in Table No.2. Alloy Steel bars of 28mm diaX110mm 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 using conventional Lathe accordingly, the MRR is measured precisely.

Table No. 1: Control Factors & Levels for MQL and 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 flooded

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

4. RESULTS & DISCUSSIONS:

Material removal rate (MRR) has been calculated using equation (1), i.e., the difference of weight of work piece before and after experiment. The weight of the specimen is measured with the help of digital weighing machine before and after machining the work piece. The machining time is also noted during the machining process for each work piece

$$MRR = \frac{1000 \times W_w}{\rho_w \times t} \text{ mm}^3/\text{min} \quad \ldots\ldots\ldots\ldots (1)$$

The MRR is measured precisely with the help of a MRR formula and the experiments results are tabulated in table no. 3& 8 for MQL and Flooded Conditions. For each experiment the corresponding S/N values at larger the better are also tabulated. Optimization of Material removal Rate is carried out using Taguchi methodology. Confirmatory tests have also been conducted to validate the optimal results.

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

EXP NO.	**MRR with MQL**			**S/N RATIO**
	TRAIL1	**TRAIL2**	**MEAN**	
1	350.27	348.12	349.19	50.86
2	4749.02	4747.9	4748.46	73.53
3	10772.1	10779.3	10775.65	80.65
4	3965.2	3966.1	3965.65	71.97
5	7954.8	7956.15	7955.47	78.01
6	629.3	620.3	624.8	55.91
7	6616.99	6620.1	6618.54	76.41
8	650.85	649.75	650.3	56.26
9	7034.9	7036.5	7035.7	76.95

Table No 4: Summary of S/N Ratios for MQL

Factor	**Level 1**	**Level 2**	**Level 3**
Speed(A)	68.34	68.63	**69.87**
Feed(B)	66.41	69.27	**71.17**
Depth of Cut(C)	39.34	74.15	**78.35**
Type of tool(D)	68.60	**68.61**	68.52

The best condition for cutting speed is level 3 (69.87), for feed is level 3 (71.17), for depth of cut is level 3 (78.35) and type of tool is level 2 (68.61). Thus, the optimum conditions chosen were: **A3-B3-C3-D2**. A confirmation test is performed with the obtained optimum cutting, the MRR is measured and the S/N ratio is calculated for the MQL condition. The conformation test results are tabulated in the table no 6.

Table No 5: Optimum Set Of Control Factors for MQL

Factors /Levels	**Speed (A) (rpm)**	**Feed (B) (mm/min)**	**Depth Of Cut (C) (mm)**	**Type of tool (D)**
Optimum Value	1500	0.8	2.5	Gold coated carbide tip

Table No 6. Conformation results (MQL)

MRR			S/N RATIO
1	2	Average	
12,870.3	12,760.1	12,815.2	82.15

From table no. 5 the following calculations are done, for all the cases the predicted value is calculated in the same procedure.
η predicted=[A3+B3+C3+D2]-3Y
= [69.87+71.17+78.35+68.61] – [3X (68.95)]
η predicted= 81.15

Therefore, the predicted average for optimum condition of material removal rate is 81.15.A confirmation test is performed with the obtained optimum cutting parameters. The material removal rate values are taken for two trials and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 7.

Table No 7. Comparison of S/N ratios for MQL

η predicted	81.15
η conformation	82.15

Table No 8: Experimental Results of MRR for Flooded with the corresponding S/N Ratio's

EXP NO.	**MRR with flooded**			**S/N RATIO**
	TRAIL1	**TRAIL2**	**MEAN**	
1	490.38	485.33	487.85	53.76
2	4609	4610.2	4609.6	73.27
3	10608.2	10605.1	10606.7	80.51
4	4109.4	4108.2	4108.8	72.67
5	8400.8	8409.87	8405.3	78.49
6	755.16	754.11	754.63	57.55
7	6689.2	6683.17	6686.18	76.50
8	939.96	936.5	938.23	59.44
9	7399.5	7293.14	7346.32	77.32

Table No 9: Summary of S/N Ratios (Flooded)

Factor	**Level 1**	**Level 2**	**Level 3**
Speed(A)	69.18	69.57	**71.08**
Feed(B)	61.32	70.4	**71.79**
Depth of Cut(C)	56.91	74.42	**78.5**
Type of tool(D)	69.85	**74.42**	70.87

The best condition for speed is level 3 (71.08), for feed is level 3 (71.79), for depth of cut is level 3 (78.5) and type of tool is level 2 (74.42). Thus, the optimum conditions chosen were: **A3-B3-C3-D2**. 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 are tabulated in the table no 11.

Table No 10: Optimum Set Of Control Factors for flooded

Factors /Levels	**Speed (A) (rpm)**	**Feed (B) (mm/min)**	**Depth Of Cut (C) (mm)**	**Type of tool (D)**
Optimum Value	1500	0.8	2.5	Gold coated carbide tip

Table No 11. Conformation results (Flooded)

MRR			S/N RATIO
1	2	Average	
16,707.9	16,530.9	16,619.4	84.41

From table no.10 the following calculations are done, for all the cases the predicted value is calculated in the same procedure.

η predicted=[A3+B3+C3+D2]-3Y

= [71..08+71.79+78.50+74.42] – [3X (69.94)]

η predicted= 85.96.

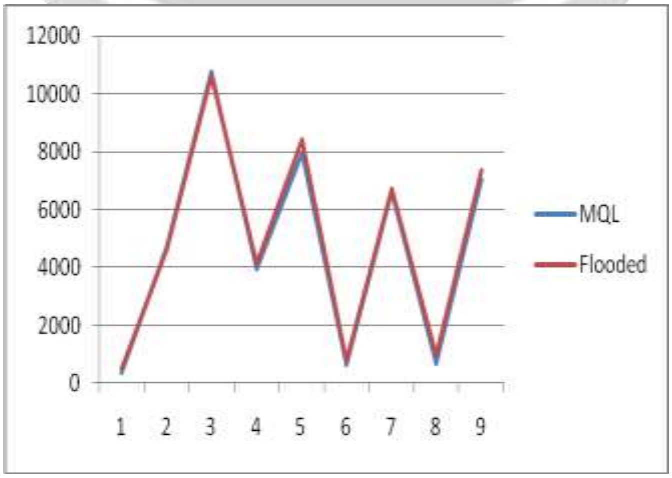
Therefore, the predicted average for optimum condition of material removal rate is 85.96.A confirmation test is performed with the obtained optimum cutting parameters. The material removal rate values are taken for two trials and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 12.

Table No 12. Comparison of S/N ratios for flooded

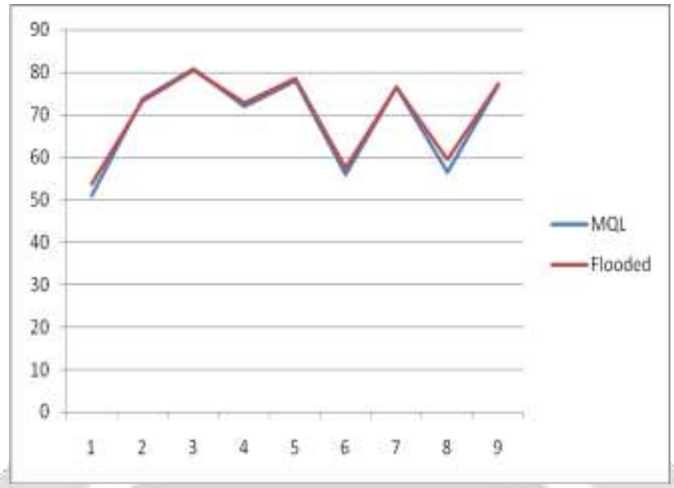
η predicted	85.96
η conformation	84.41

4.1. Comparsion of MQL and Flooded Nano fluid:

Comparison of MQL and Flooded mean results are plotted in Graph No. 1 in the terms of MRR, the graph shows comparatively equal results for both MQL and Flooded conditions. Similarly the S/N ratios are plotted in Graph No. 2, which shows same conditions under MQL and Flooded.



Graph no 1: MQL vs Flooded for MRR Mean



Graph no 2: MQL vs Flooded for S/N ratios

5. 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. Based on the results of the present experimentation the following conclusions are drawn:

- In the present experimentation the optimum speed obtained using Taguchi Robust Design Methodology is 1500 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 Gold coated carbide tip for MQL conditions.
- For Flooded conditions the optimum speed obtained using Taguchi Robust Design Methodology is 1500 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 Gold coated 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 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.

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