Experimental Investigation of Turning of Steel Alloy Under Sae40+Boric Acid

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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 solid and liquid lubricant mixture of SAE 40 + Boric Acid in order to improve material removal rate. 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 work piece material used is EN 353 Alloy Steel. Experiments are carried out using L9 (34) orthogonal array.

Key words: Taguchi Method, EN-353 Material, Material Removal Rate, SAE 40, Boric Acid

I. 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 [1]. Application of solid-liquid 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. Boric acid (H3BO3) is one of the most popular solid lubricant and has excellent lubrication properties without calling for expensive disposal techniques. The most important characteristics of boric acid for use as a lubricant are that it is readily available and cheap and environmentally safe. Several studies related to the lubrication properties of boric acid are carried out over the past several decades [10], [11]

II. DETAILS OF EXPERIMENTATION

In the present work the turning operations is carried out using CNC Lathe shown in the fig no.1. The work material selected is EN-353 steel alloy shown in fig.no.2. The machining tests are conducted under the different conditions of Cutting speed, Feed rate, Depth of cut and different types of tool using L_9 (3^4) orthogonal array .

Fig. 1: CNC Turning Machine


Fig. 2: EN353 Steel Alloy

The cutting inserts used for machining are CNMG carbide tools of KORLEY Company, which are

- UNCOATED tool with grade T20 (shown in Fig. 3)
- PVD coated with grade PC 9030(shown in Fig. 4)
- CVD coated with grade NC 3010 (shown in Fig. 5)

Fig. 3: Uncoated Carbide Tool Insert

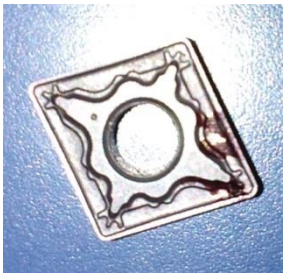

Fig. 4: PVD Coated Carbide Tool Insert

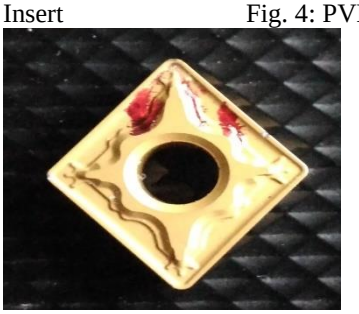

Fig. 5: CVD Coated Carbide Tool Insert

A solid-liquid lubrication is provided in the machining. The cutting fluid used is mixture of SAE 40 + water(H_2O), at a ratio of 1:20.

Fig. 6: Lubrication SAE 40+Boric acid

Steel bars of 30mm diaX150mm length are prepared for conducting the experiment. Using different levels of the process parameters the specimens have been machined in CNC Lathe Machine accordingly shown in fig. no. 7, as per the experimental design shown in table no.2. 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

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

Where, $W_w = W_i - W_f$ W_i is the initial weight of work piece in gms; W_f is the final weight of work piece in gms; t is the machining time in minutes; ρ_w is the density of EN 353 steel alloy

The Investigation presents the use of Taguchi method for optimizing the material removal rate in turning medium EN353 which is extensively used as a main engineering material in various industries such as Rollers, Supporting shafts, and Structural column etc.

The experiments designed using Taguchi Robust Design Methodology with four control factors i.e. cutting speed (A), feed rate (B), depth of cut(C) and types of tool (D) selected with three levels and the corresponding orthogonal array are chosen with respect to its degrees of freedom.

Factors/Levels	**Speed (A)**	**Feed (B)**	**Depth of Cut (C)**	**Type of Tool (D)**
1	849	0.05	0.2	Un-Coated
2	1379	0.125	0.53	PVD
3	1910	0.2	0.3	CVD

Table 1: Control Factors and Levels

Experiment Number	**Column**			
	Speed (A)	**Feed (B)**	**Depth Of Cut (C)**	**Type Of Tool (D)**

1	849	0.05	0.2	Un-Coated
2	849	0.125	0.35	CVD
3	849	0.2	0.5	PVD
4	1379	0.05	0.35	PVD
5	1379	0.125	0.5	Un-Coated
6	1379	0.2	0.2	CVD
7	1910	0.05	0.5	CVD
8	1910	0.125	0.2	PVD
9	1910	0.2	0.35	Un-Coated

Table 2: Experimental Design

Fig. 7: Machining of Work Piece EN 353 Alloys with SAE 40+ Boric Acid

III. RESULTS AND DISCUSSIONS

The material removal rate is calculated with the formulae from eq. 1 and the corresponding results and S/N ratios are tabulated in Table no. 3. For each experiment the corresponding S/N values are also tabulated. Optimization of MRR is carried out using Taguchi method. Confirmatory test have also been conducted to validate optimal results.

Exp. no	**MRR**	**S/N**
1	798.466	58.04
2	412.54	52.30
3	3018.59	73.11
4	937.59	59.44
5	1509.29	63.57
6	3750.37	71.48
7	4950.49	73.89
8	3094.06	69.81
9	3094.059	69.81

Table 3: Experimental Data for Material Removal Rate

Factor	**Level 1**	**Level 2**	**Level 3**
Speed(A)	61.15	64.83	**71.17**
Feed(B)	63.79	61.89	**71.46**
Depth of Cut(C)	66.44	60.51	**70.19**
Type of Tool (D)	63.80	65.89	**67.45**

Table 4: Summary of S/N Ratios

The best condition for Spindle Speed factor is level 3 (180m/min), for Feed Rate is level 3 (0.2mm/rev), for Depth of Cut is level 3 (0.5 mm) and Type of Tool is level 2 (CVD). Thus, the optimum conditions chosen were: **A3-B3-C3-D3**.

Factors/Levels	Speed(A) (m/min)	Feed(B) (mm/rev)	Depth of Cut(C) (mm)	Type of Tool(D)
Optimum Value	1910	0.2	0.5	CVD

Table 5: Optimum Set Of Control Factors

From table no. 5 the following calculations are done, for all the cases the predicted value is calculated in the same procedure.

$$\eta_{predicted}=[\ A3+B3+C3+D3]-3Y$$
$$= [71.17+71.46+70.19+67.45] – [3X\ (65.71)]$$
$$\eta_{predicted}= 83.146$$

Therefore, the predicted average for optimum condition of material removal rate is 83.146

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 6 & 7.

MRR Value	S/N Ratio
10890.16	80.14

Table 6: Conformation Test Results

η predicted	83.146
η confirmation	80.14

Table 7: Comparison Of S/N Ratios

From Figure No 9, it is observed that, the MRR is high at high cutting speed conditions and increasing from low cutting speed to moderate speed conditions, but from moderate to high cutting speeds.

From Figure No 10, it is observed that, the hardness is high at low Feed Rate conditions and certainly decreasing from low feed rate to moderate and from moderate to high feed rate, the MRR increases.

From Figure No 11, it is observed that, the MRR is low at small depth of cut and certainly increasing from small depth of cut to moderate depth of cut conditions, and from moderate to high depth of cut, the MRR increases.

From Figure No 12, it is observed that, the MRR is low for UNCOATED tool and the MRR is slightly increasing when CVD tool is used than to UNCOATED tool, compared to CVD and UNCOATED tool PVD coated tool has high MRR .

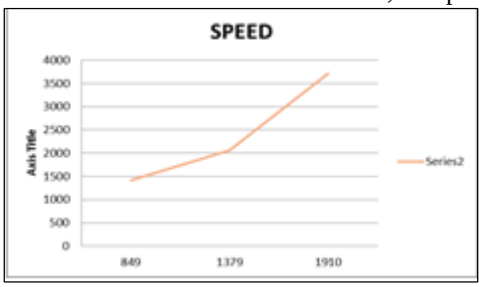

Fig. 8: MRR V/s Cutting Speed

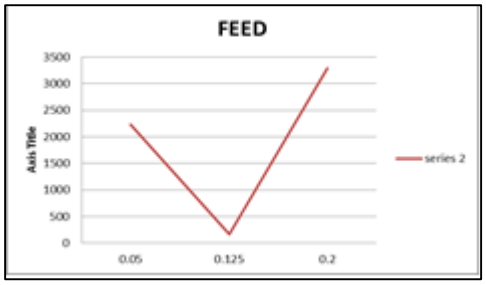

Fig. 9: MRR V/s Feed Rate

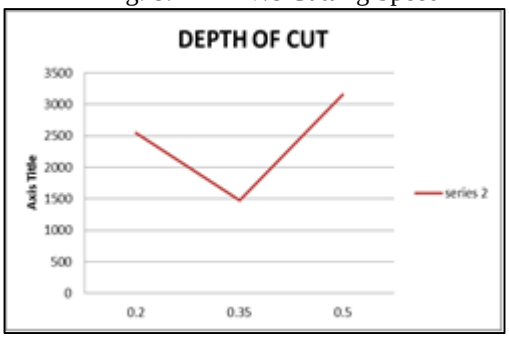

Fig. 10: MRR V/s Depth of Cut

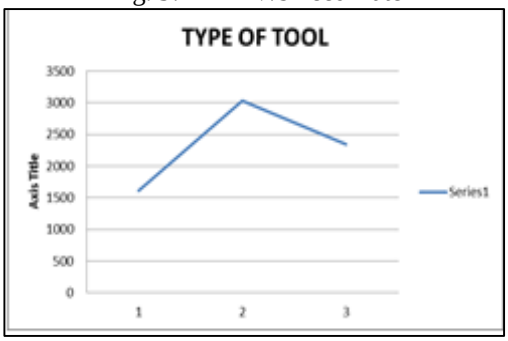

Fig. 11: MRR V/s type of tool

IV. CONCLUSION

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 selected 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 Tauguchi Robust Design Methodology is 1910 rpm. Similarly the results obtained for feed and depth of cut are 0.2mm/min and 0.5mm respectively.
- The corresponding Type of tool is CVD coated.
- The S/N ratio of predicted value and verification test values are valid when compared with the optimum values. 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.

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