Optimization of Process Parameters in Turning of En-353 for Material Removal Rate

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Abstract— There is a development of new materials every day and for each new material, we need economical and efficient machining. Taguchi is one of the good method for optimization of various machining parameters that reduces number of experiments. The objective of this paper is to develop the Taguchi optimization method using Lubricant for high material removal rate in terms of process parameters, in turning of EN-353 steel, considering the process parameters as cutting speed, feed rate, depth of cut, type of tool. A series of turning experiments were performed to measure material removal rate. Taguchi orthogonal arrays, signal-to-noise(S/N) ratio are used to find the optimal levels and the effect of the process parameters on material removal rate.

Key words: S/N Ratio, Taguchi Method, EN-353 alloy Steel, Lubricant, Orthogonal Array etc

I. INTRODUCTION

Lubrication is the process or technique employed to reduce friction between, and wear of one or both, surfaces in proximity and moving relative to each other, by interposing a substance called a lubricant in between them. A proper combination of Lubricant is extremely important because this determines surface quality of manufactured parts. The cutting fluids/ Lubricants serve many useful functions including, cooling of the cutting tool at higher speeds, lubricating at low speeds and high loads, increasing tool life, improving the surface finish, reducing the distortion due to temperature rise in the work piece, facilitating chip handling and disposal, providing a protective layer on the machined surface from oxidation and protecting the machine tool components from rust. But the application of conventional cutting fluids creates some environmental problems like environmental pollution, water pollution, and biological problems to operators [1]. The objective of the present work is to find out the set of optimum condition for the selected process parameters in order to improve material removal rate using Lubricant. Taguchi method is used to determine the optimum process parameters viz. cutting speed, feed rate, depth of cut and type of tool at three different levels.

II. LITERATURE REVIEW

Thorough literature survey has been carried out, the literature survey helped in proper selection of input parameters, issues related to Taguchi method and Selection of Lubricant for machining.

III. EXPERIMENTATION DETAILS

The turning operations (facing) are carried out on CNC Lathe machine shown in fig no.1. The machining tests are conducted under the different conditions of Cutting speed, Feed rate, Depth of cut and different types of tool using L9 (34) orthogonal array.

Fig. 1: CNC Turning Machine

The work material selected in the present work is EN-353 steel alloy. EN 353 is nickel- chromium high hardenability, case hardening (carburizing) steel. The composition of EN 353 Alloy is tabulated in the Table no 1 and the corresponding alloy round bars of 30mm diameter and 150mm length shown in figure no.2.

Element	Weight percentage (%)
C	0.18
Mn	0.72
Si	0.21
Ni	1.26
Cr	0.89
Mo	0.12
S	0.028
P	0.030

Table 1. Composition of EN-353 Steel Alloy

Fig. 2: EN353 Steel Alloy

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

- UNCOATED (shown in Fig. 3)
- PVD coated (shown in Fig. 4)
- CVD coated (shown in Fig. 5)

Fig.3: Uncoated Carbide Tool Insert

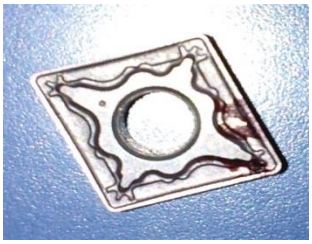

Fig. 4: PVD Coated Carbide Tool Insert

Fig. 5: CVD Coated Carbide Tool Insert

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. These materials are considered as easy to machining and possess superior mach inability. Taguchi's orthogonal arrays are highly fractional designs, used to estimate main effects using only few experimental runs. These designs are not only applicable to two level factorial experiments, but also can investigate main effects when factors have more than two levels. 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 [2,5].

Lubrication is the process, or technique employed to reduce wear of one or both surfaces in close proximity, and moving relative to each other, by interposing a substance called lubricant. Here the lubricant used is mixture of SAE 40+ water(H2O), at a ratio of 1:20.

Fig. 6: Lubrication SAE 40

IV. DESIGN OF EXPERIMENTS

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, as per the experimental design shown in table no.3. Then the MRR is calculated [6], the results of the experiments have been shown in table no 4.

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 2. 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 3. Experimental Design

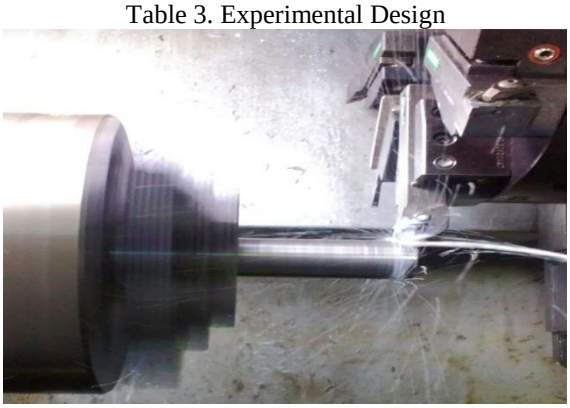

Fig. 7: Machining of Work Piece EN 353 Alloy

V. RESULTS AND DISCUSSIONS

The MRR is measured precisely and the results are tabulated in table no 4. 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	276.258	48.826
2	644.662	56.186
3	1161.008	61.296
4	1109.016	60.898
5	2009.242	66.060
6	1856.458	65.373
7	5863.956	75.323
8	1688.048	64.547
9	4374.453	72.818

Table 4. Experimental Data for Material Removal Rate

Factor	Level 1	Level 2	Level 3
Speed(A)	55.436	64.110	70.896
Feed(B)	61.682	62.474	66.495
Depth of Cut(C)	59.582	63.300	67.559
Type of Tool (D)	62.568	65.836	63.967

Table 5. Summary of S/N Ratios

A. Selection Of Optimum Set Of Conditions For Material Removal Rate

The best condition for Spindle Speed factor is level 3 (1910rpm), 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-D2.

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

Table 6. Optimum Set Of Control Factors

B. Prediction Of Process Average For Optimum Condition For Material Removal Rate

From table no. 6 the following calculations are done, for all the cases the predicted value is calculated in the same procedure.

ηpredicted=[A2+B3+C2+D2]-3Y

= [70.896+66.495+67.559+65.836] – [3X (63.480)]

ηpredicted= 80.346

Therefore, the predicted average for optimum condition of material removal rate is 80.346.

C. Performing Verification Test For MRR

A confirmation test is performed with the obtained optimum cutting parameters. The material removal rate values are taken and the S/N ratio is calculated for this condition. The conformation test and the predicted values are tabulated in the table no 7 & 8.

MRR VALUES	S/N RATIO
7288.46	77.257

Table 7. Conformation Test Results

$\eta_{predicted}$	80.346
$\eta_{conformation}$	77.257

Table 8. Comparison Of S/N Ratios

D. Effect Of Cutting Parameters On Material Removal Rate

From Figure No 8, it is observed that, the material removal rate is low at low cutting speed conditions and increasing from low cutting speed to moderate speed conditions, and from moderate to high cutting speeds, the material removal rate is increasing.

From Figure No 9, it is observed that, the material removal rate is high at low Feed Rate conditions and certainly decreasing from low feed rate to moderate and from moderate to high feed rate, the material removal rate increases.

From Figure No 11, it is observed that, the material removal rate 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 material removal rate increases.

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

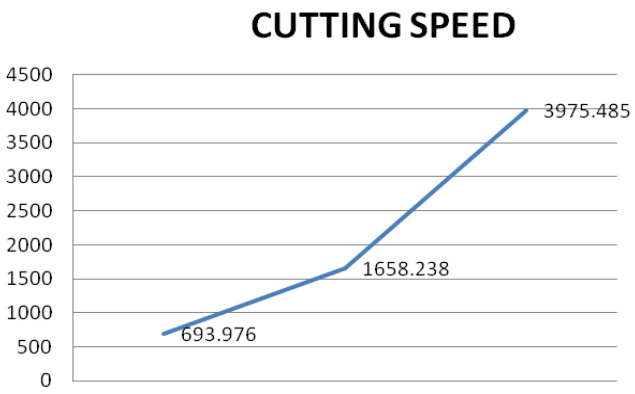

Fig. 8: MRR V/s Cutting Speed

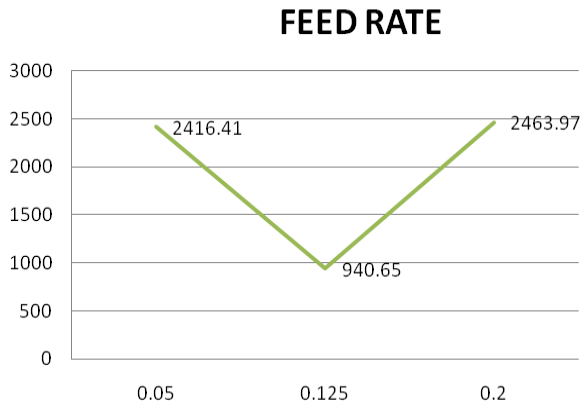

Fig. 9: MRR V/s Feed Rate

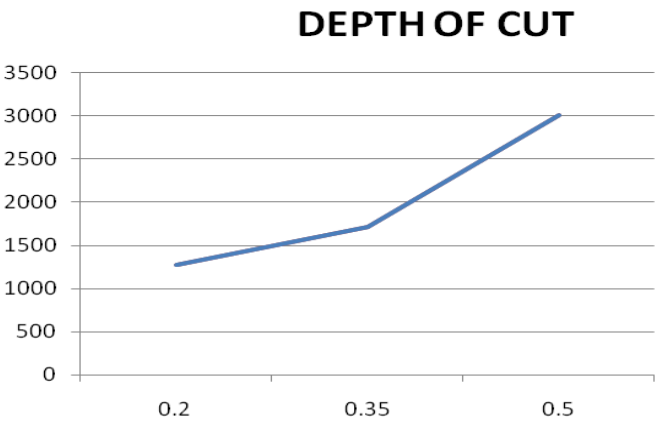

Fig. 10: MRR V/s Depth of Cut

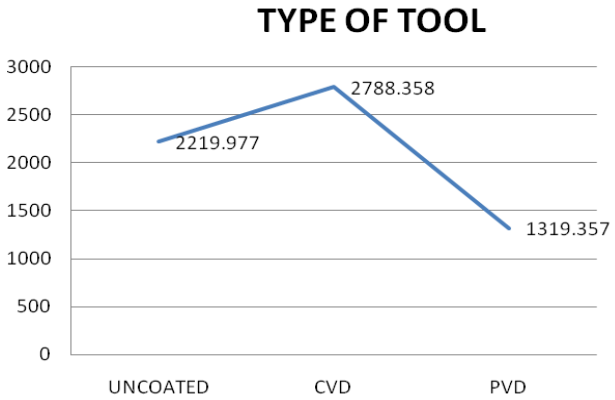

Fig. 11: MRR V/s type of tool

VI. CONCLUSION

The theme of the paper is to find out the set of optimum conditions in order to improve hardness, using Taguchi's techniques with the help of SAE 40 Lubricant and considering the 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 1910rpm. 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.

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