Experimental Study on the High Speed Machining of Steel Alloy

Venkata Vishnu[1] G.Guruvaiah Naidu[2] Posani Srikanth[3] S.Venkat Chowdary[4] S.Sai Sharan[5]
[1,2]Assistant Professor [3,4]Student
[1,2,3,4]Department of Mechanical Engineering
[1,2,3,4]Nalla Narasimha Reddy Education Society's Group of Institutions, Hyderabad, Telangana State, India

Abstract— This present paper outlines an experimental study to optimize the effect of selected machining parameters i.e. Cutting Speed, Feed rate, Depth of cut and Type of tool for EN-353 Alloy steel under High speed machining Conditions by employing Taguchi Design Methodology. Taguchi Design methodology stresses the importance of studying the response variation using the Signal to Noise Ratio (S/N Ratio), resulting the maximization of quality characteristic. Material removal rate is considered as the quality characteristic parameter in the concept of "the Larger the better type". MRR values are measured from the experiment, and their optimum values are calculated. The S/N ratio of predicted value and verification test values are valid when compared with the optimum value. It is found that S/N ratio value of verification test is within the limits of predicted value and the objective of the work is full filled.

Key words: Cutting Speed, Feed Rate, Depth of Cut, Type of Tool, High Speed Machining, EN-353 Alloy Steel, Material Removal Rate

I. INTRODUCTION

The objective of the present work is to find out the set of optimum cutting parameters for the selected Turning machining parameters in order to improve Material Removal Rate under High speed machining. Taguchi methodology 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 L_9 (3^4) orthogonal array. The output parameter is MRR.

II. LITERATURE REVIEW

Literature survey reveals that a considerable amount of work has been carried out by previous investigators for optimization of the product in turning operation, Issues related to metal removal rate etc., have been addressed too. Optimizing a response (process output), have been solved using Taguchi method [5]. These studies all discovered clear and useful correlations between their control and response parameters A thorough study of literature [1-10] has been carried out.

III. EXPERIMENTAL

The work material selected in the present work is EN-353 steel alloy. The turning operations are carried out on CNC Lathe machine. The machining tests are conducted under the different conditions of Cutting speed, Feed rate, Depth of cut and different types of tools using L9 (3^4) orthogonal array .

A. Specifications of CNC Turning Machine:

The experiments are conducted on CNC Lathe shown in Figure No.1.

Fig. 1: CNC Turning Machine

B. Work Piece Material:

In order to ensure the material of the specimen is done with help of the Chemical Analysis Report. The result is obtain from the chemical analysis, carbon - 0.18%, silicon - 0.21%, manganese - 0.72%, phosphorus - 0.030%, Sulphur - 0.028%, Chromium – 0.89%, Nickel – 1.26%, molybdenum - 0.12% and remaining percentage is iron respectively. A sample of 32 ×155mm is selected to find the chemical composition of the material. After ensuring the chemical composition, the raw material is machined according to the dimension for various tests.

Element	Weight percentage (%)
C	0.18
Mn	0.72
Si	0.21
S	0.028
P	0.030
Cr	0.89
Ni	0.1.26

Table 1: Composition of EN-353 Steel Alloy

Fig. 2: EN 353 Steel Alloy

C. Cutting Inserts:

The cutting inserts used are TNMG carbide tools of KORLOY Company, which are

- UNCOATED tool with grade T20 (shown in Fig. 3)
- PVD coated (TiAlN+TiN) with grade PC 9030(shown in Fig. 4)
- CVD coated (CVD Al_2O_3 film MT-TiCN + TiC + Al_2O_3) with grade NC 3010 (shown in Fig. 5)

Fig. 3: Uncoated Carbide Tool Insert

Fig. 4: CVD Coated Carbide Tool Insert

Fig. 5: PVD Coated Carbide Tool Insert

D. Tool Holder:

The specification of tool holder used for machining is BT30-ER16, side lock adapter system shown in figure no.6.

Fig. 6: Tool Holder & Chuck

E. Weighing Machine:

Weighing machine is used to find the weight of the given specimens before and after the machining. With this we can calculate the MRR.

Fig. 7: Weighing Machine

F. Design of Experiments:

The experiments designed using Taguchi Method 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 $L_9(3^4)$ are chosen with respect to its degrees of freedom [1,4].

Steel bars of 32mm diaX155mm 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. Then MRR is measured precisely with the help of weighing machine initial and final weights are found outed and MRR is calculated. The results of the experiments have been shown in table no 5[1].

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	0.35	CVD
3	1910	0.2	0.5	PVD

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. 8: Machining of Work Piece EN 353 Alloy steel.

IV. RESULTS AND DISCUSSIONS

Then Material Removal Rate is measured precisely with the help of a formula [5] and the results are tabulated in table no 5. For each experiment the corresponding S/N values are also tabulated. Optimization of MRR is carried out using high machining. Confirmatory test have also been conducted to validate optimal results.

Experiment No.	**MRR** (mm^3/min)	**S/N Ratio** (η)
1	423.84	52.54
2	1289.19	62.20
3	2190.48	66.81
4	1714.16	64.68
5	4638.76	73.32
6	4641.08	73.33
7	9282.17	79.35
8	4373.22	72.81
9	4950.49	73.89

Table 4: Experimental Data for MRR

Factor	**Level 1**	**Level 2**	**Level 3**
Speed(A)	60.52	70.44	**75.35**
Feed(B)	65.52	69.43	**71.345**
Depth of Cut(C)	66.23	66.92	**73.16**
Type of Tool (D)	66.58	**71.63**	68.10

Table 5: Summary of S/N Ratios

A. Selection of Optimum Set of Conditions for MRR:

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

Factor	Speed (rpm)	Feed (mm/rev)	D.O.P (mm)	Type of Tool
Optimum value	1910	0.2	0.5	CVD

Table 6: Optimum Set Of Control Factors

B. Prediction of Process Average for Optimum Condition for MRR:

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

$\eta_{predicted}$= Y+ (A3-Y) + (B3-Y) + (C3-Y) + (D2-Y)

= A3+B3+C3+D2-3Y

= [(75.35) + (71.345) + (73.16) + (71.63)] – [3X (68.773)]

$\eta_{predicted}$=85.17

Therefore, the predicted average for optimum condition of MRR is 85.17.

C. Performing Verification Test for MRR:

A confirmation test is performed with the obtained optimum cutting parameters. The Hardness 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.the corresponding.

MRR VALUE	S/N RATIO
12284.19	**81.786**

Table 7: Confirmation test values

$\eta_{predicted}$	85.17
$\eta_{conformation}$	81.786

Table 8: Comparison of S/N Ratios

D. Effect of Cutting Parameters on MRR:

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 up to high cutting speeds.

From Figure No 10, it is observed that, the MRR 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 decreasing 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 PVD tool and the MRR is slightly increased when UNCOATED tool is used than to PVD tool, compared to PVD and UNCOATED tool CVD coated tool has high MRR.

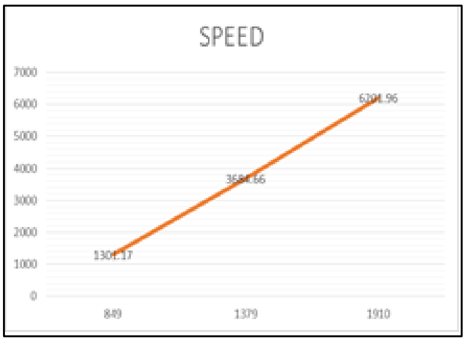

Fig. 9: MRR V/s Cutting Speed

Fig. 10: MRR V/s Feed Rate

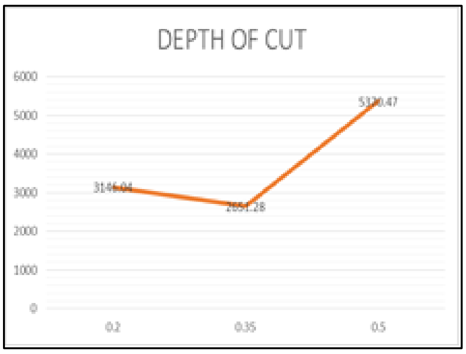

Fig. 11: MRR V/s Depth of Cut

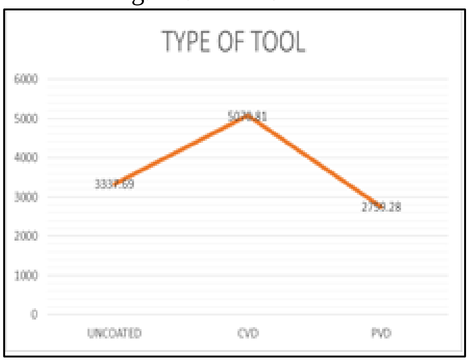

Fig. 12: MRR V/s type of tool

V. CONCLUSION

The theme of the paper is to find out the set of optimum conditions in order to improve MRR, using high speed machining 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 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.
- 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 [1].

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