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Effect of Cutting Parameters on Surface Quality of Mild Steel (Grade A) in CNC Turning – A Case Study

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Abstract: surface quality is one of the prime requirements of customers for machined parts. the present work deals with the study of effect of cutting parameters on surface hardness of mild steel (m.s.) is-2062 grade-a in cnc turning under conventional cooling condition. taguchi method has been employed in the optimization of cutting parameters-such as speed, feed and depth of cut. the turning experiments under conventional cooling were planned as per taguchi's l9 orthogonal array (o.a.) which is designed with three levels of turning parameters. signal to noise (s/n ratios) were calculated to determine the optimal parameter levels and obtain the level of importance of the cutting parameters, respectively. validation tests with optimal levels of parameters were performed to demonstrate the effectiveness of taguchi optimization. the optimization results revealed that depth of cut plays important role in maximizing the hardness.

Keywords: CNC Turning, Optimization, Orthogonal Array, Surface Hardness, Taguchi.

I. INTRODUCTION

Machining is the most wide spread metal machining process in mechanical manufacturing industry. The goal of changing the geometry of raw material in order to form mechanical parts can be met by putting material together. Conventional machining is the one of the most important material method. Machining is a part of the manufacturing all most all metals products. In order to perform cutting operations, different machining tools such as lathes, drilling machine, horizontal and vertical milling machines etc. are utilizing. [2]

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface-

- With the work piece rotating,
- With a single-point cutting tool,
- With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work. [11] The objective of this research is to study the effect of cutting speed, feed and depth of cut on Hardness.

From the previous studied, it is evident that although researchers have tried to investigated the relation of surface roughness with different process parameters of different machining operations like drilling, milling etc. but there is a gap in determining of the exact affect of speed, feed and depth of cut on Surface hardness of work piece in turning operation. Therefore this aspect has been selected in this research paper.

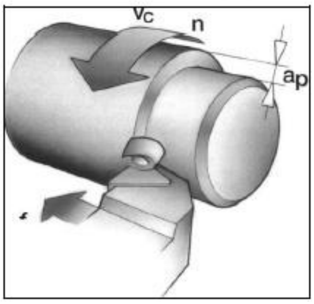

Figure 1.Turning Process [11]

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A. Taguchi Method

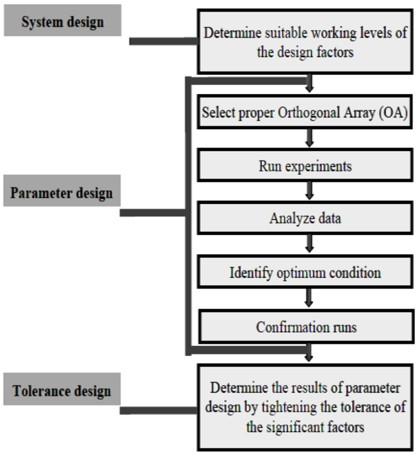

Figure 2. Flow Chart of Taguchi Robust Design [9]

Taguchi robust design method is a most powerful tool for the design of a high-quality system. He considered three steps in a process's and product's development: system design, parameter design, and tolerance design. In system design, the engineer uses scientific and engineering principles to determine the fundamental configuration. In the parameter design step, the specific values for system parameters are determined. Tolerance design is used to determine the best tolerances for the parameters. [6]

Table I: Summary of Literature Review

Authors	Work piece Material	Optimum Parameter Values	Hardness HRC
Prajwalkumar M. Patil, Rajendrakumar V. Kadi, Dr. Suresh T. Dundur, Anil S. Pol 2015	AISI 316 Austenitic Stainless Steel	Cutting speed=80m/min, Feed=0.3 mm/rev, Depth of cut=1.5 mm	25
Ashish Yadav, Ajay Bangar, Rajan Sharma, Deepak Pal 2012	EN 8 steel	Spindle Speed = 1450rpm, Feed rate = 0.45 mm/rev, Depth of cut = 1.0 mm,	32
AL. Arumugam, and R. Ragothsingh 2013	Forged steel EN353	Speed = 1990 r/min., Feed rate = 0.3 mm/min, Depth of cut = 1.00 mm.	14
Goutam Devaraya Revankar, Raviraj Shetty, Shrikantha Srinivas Rao, Vinayak Neelakanth Gaitonde 2014	Titanium Alloy	Lubricating mode=Dry Cutting Speed=150 m/min Feed =0.15mm/rev Nose Radius =0.6mm Depth of cut=0.75mm	36
Komson Jirapattarasilp and Choobunyen Kuptanawin 2012	Stainless Steel: SUS 303	-----	13

A.1 Signal to Noise Ratio

This variation of index is called as signal to noise ratio (S/N). The S/N ratio is used to optimize the signal value. It is basically of three types.

Nominal-is-the-best

$$\frac{S}{N_T} = 10\log\left(\frac{\bar{y}}{s_y^2}\right)$$

Larger-is-the-better (maximize)

$$\frac{S}{N_L} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$$

Smaller-is-the-better (minimize)

$$\frac{S}{N_L} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n}y_i^2\right)$$

Where y, is the average of observed data, sy2 is the variance of y, n is the number of observations and y is the observed data. Notice that these S/N ratios are expressed on a decibel scale. We would use S/N_T if the objective is to reduce variability around a specific target, S/N_L if the system is optimized when the response is as large as possible, and S/NS if the system is optimized when the response is as small as possible. Factor levels that maximize the appropriate S/N ratio are optimal. [12] The aim of this research was to produce maximum hardness in a turning operation. Larger value represents better hardness. Therefore, a larger-the-better quality characteristic was implemented and introduced in this study.

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EXPERIMENTAL SET-UP AND CUTTING CONDITION

A. Work Piece Material

The work piece material used is Mild Steel belongs to steel alloy of 540mm long, with 30 mm diameter of round bar.

TABLE II: CHEMICAL COMPOSITION OF MILD STEEL ALLOY (IS-2062 GRADE A)

Element	**Chemical Composition (wt. %)**
C	0.23 %
Si	0.40 %
Mn	1.50 %
S	0.05 %
P	0.05 %

B. Design of Experiments

B.1 Selection of control factors and levels

A total of three process parameters with three levels are chosen as the control factors such that the levels are sufficiently far apart so that they cover wide range. The process parameter and their ranges are finalized using literature, books and machine operator's experience. The three control factors selected are spindle speed (A), feed rate (B), depth of cut(C).Mild Steel alloy work pieces are used in experimentation. The control levels and their alternative levels are listed in table.

TABLE III: CONTROL FACTORS AND LEVELS

Control Factors	Unit	Levels		
		Level 1	Level 2	Level 3
Cutting speed, V	rev min-1	400	800	1200
Feed rate, f	mm min-1	40	80	120
Depth of cut, d	Mm	1	1.5	2

B.2 Selection of Orthogonal Array

Selection of particular orthogonal array from the standard O.A depends on the number of factors, levels of each factor and the total degrees of freedom.

- Number of control factors = 3
- Number of levels for each control factors = 3
- Total degrees of freedom of factors = factors x (levels-1) = 3 x (3- 1) = 6
- Number of experiments to be conducted = 9

Based on these values and the required minimum number of experiments to be conducted 9, the nearest Orthogonal Array fulfilling this condition is L9 (3^3).

TABLE IV.STANDARD L9 (3^3) ORTHOGONAL ARRAY

Test Number	Column Number		
	1	2	3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

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B.3 Plan of Experiments

The scope and objective of the present work have already been mentioned in the forgoing cases. Accordingly, the present study has been done through the following plan of experiment.

1. Checking and preparing the CNC turning ready for performing the machining operation.
2. Cutting Mild Steel Alloy (IS-2062 Grade A) by power saw and performing turning operation in CNC turning to get desired dimension of the work pieces.
3. Selection of appropriate tool depending upon the cutting parameters i.e. speed, feed and depth of cut is done depending upon the experiment design.
4. Cutting parameters speed, feed, and depth cut are selected going through the study of different literature and also in the view of machine standard specifications.
5. Performing turning operation on MS specimens in various turning environments and various combinations of process control parameters like: speed, feed, depth of cut.
6. Measuring hardness of specimen using Rockwell Hardness Testing machine in HRC.

B.4 Program Used For Machining

Main Program

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G99 G21;
M03 S1200;
T0101;
G00 X32 Z10;
G00 X30 Z1;
G94 X-1 Z-0.3 F1;
G00 X30 Z1;
G71 U0.3 R1;
G71 P1 Q2 F1;
N1 G0 X28.5;
G01 X28.5 Z-20;
N2 G0 X40;
G0 X40 Z100 M05;
M02;
%
```

RESULT & DISCCUSSION

Mild Steel alloy pieces of Ø30 x 60mm are prepared for conducting the experiment. Using different levels of the process parameters the specimens have been machined accordingly, depending upon speed, feed and depth of cut conditions. Then hardness is measured with the help of Rockwell Hardness testing machine. The results of the experiments have been shown in table.

TABLE V.S/N RATIO CALCULATION FOR HARDNESS

Expt. No.	Columns			Hardness Trial Point 1HRC	Hardness Trial Point 2HRC	Hardness(HRC) mean	S/N ratio
	Speed(A) rev/min	Feed(B)mm/min	Depth of Cut (C)mm				
1	400	40	1	57	61	59	35.402
2	400	80	1.5	61	54	57.5	35.145
3	400	120	2	54	51	52.5	34.393
4	800	40	1.5	53	52	52.5	34.402
5	800	80	2	53	52	52.5	34.402
6	800	120	1	61	60	60.5	35.634
7	1200	40	2	54	52	53	34.481
8	1200	80	1	62	60	61	35.703
9	1200	120	1.5	52	55	53	34.557

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TABLE VI.: RESPONSE TABLE FOR SIGNAL TO NOISE RATIOS LARGER IS BETTER

Parameters	**Level 1**	**Level 2**	**Level 3**
Spindle Speed (A)	56.33*	55.167	55.83
Feed (B)	54.83	57*	55.5
Depth of Cut (C)	60.166*	54.5	52.66

From Figure 3, it is observed that, the Hardness is high at low spindle speed and suddenly Decreasing from low spindle speed to moderate spindle speed conditions, but again from moderate to high spindle speed, the hardness increases.

From Fig. 4, it is observed that, the Hardness is low at low feed rate and increasing from low feed rate to moderate feed rate conditions, but again from moderate to high feed rate, the hardness decreases.

From Figure 5, it is observed that, the Hardness is high at low Depth of cut and certainly Decreasing from low Depth of cut to moderate Depth of Cut conditions, but again from moderate to high Depth of Cut, the surface roughness decreases.

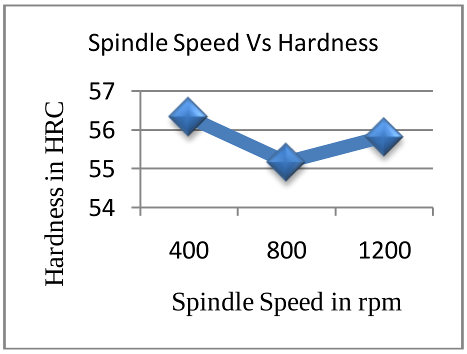

Figure 3.Spindle speed Vs Hardness

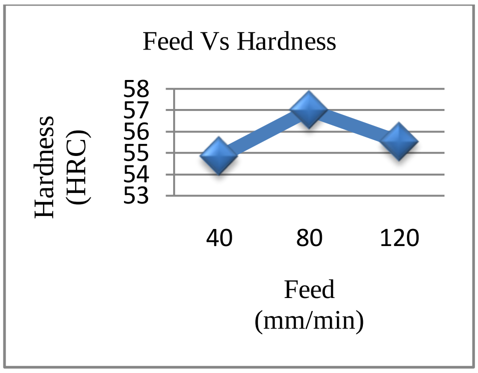

Figure 4.Feed Vs Hardness

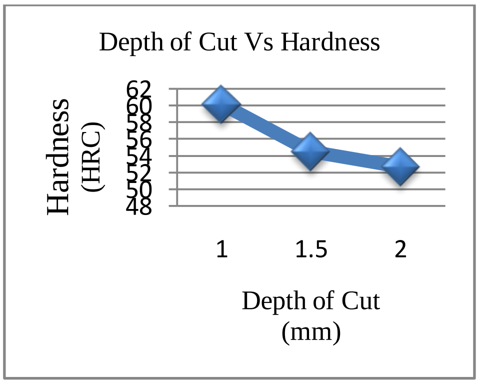

Figure 5.Depth of cut Vs Hardness

A. Optimization of Cutting Parameters

Taguchi's robust design methodology has been successfully implemented to identify the optimum settings ($A_1B_2C_1$) for control parameters in order to have high hardness of the selected work piece material for their improved performance, after analysis of data from the robust design experiments the optimum setting are found is tabulated. These optimum settings combination is validated by conducting confirmation test, which concluded that the results (Table No. 8 and 9) were within the acceptable limits of the predicted value and can be implemented in the real time application.

The estimated average value for hardness can be calculated using the following prediction equation,

$\eta_{opt} = \eta_m + (A1 - \eta_m) + (B2 - \eta_m) + (C1 - \eta_m)$

Where, ηopt = predicted optimum surface roughness average,

η_m = overall average of all the experimental data for surface roughness.

Hence, $\eta_{opt} = 62.052$ HRC

TABLE VII.OPTIMUM PARAMETERS FOR SURFACE ROUGHNESS

Factors	Optimum Values
Speed (rpm)	400
Feed(mm/min)	80
Depth of Cut(mm)	1

TABLE VIII.CONFORMATION TEST RESULTS

Surface Hardness Values HRC	S/N Ratio DB
61	35.706

TABLE IX.COMPARISON OF S/N RATIOS

Ƞpredicted	62.052	38.865
Ƞconformation	61.000	35.706

A1, B2 and C1 are the responses at the optimum levels of all the main effects. It shows the comparison of the predicted Hardness with the actual Hardness using the optimal machining parameters. The experimental results confirm the validity of the utilized Taguchi method for improving the machining performance and optimizing the machining parameters.

S/N ratio of prediction,

$Ƞ\text{prediction} = -10 * \text{Log}_{10} [\ \frac{1}{n}\Sigma\ (Y^{-2})]$

Ƞprediction = 38.865 DB

II. CONCLUSION

The objective of the present work is to find out the set of optimum values of surface hardness, using Taguchi's robust design methodology considering the control factors for the Mild steel work piece material. Based on the results of the present experimental investigations the following conclusions can be drawn,

- The literature is rich in terms of previous work.
- Depth of cut is statistically significant factor influencing the Hardness in turning process followed by feed and speed.
- In the present experimentation the optimum speed obtained using taguchi technique is 400 rpm. Similarly the results obtained for feed and depth of cut are 80m/min and 1mm respectively. Hence it can be concluded that the parameters obtained are valid and within the range of machining standards.
- 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 withinthe limits of the predicted value and the objective of the work is full filled.

III. FUTURE SCOPE

In the present work, the optimum values are obtained using taguchi technique. Hence there is a large scope of future work to be carried.

- Using taguchi robust design methodology, only the optimum values are obtained for the selected control factors, where future work can be carried out by selecting the factors to be significant or insignificant using ANOVA technique or by some other standard techniques.
- Standard Analysis techniques can be used for analyzing the data obtained for Hardness.

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