International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

Vol.4., Issue.1., 2016
(Jan-Feb)

REVIEW ARTICLE

ISSN: 2321-7758

CASE STUDY: INVESTIGATIONAL SURVEY AND OPTIMIZATION OF MACHINING PARAMETERS FOR SURFACE ROUGHNESS IN CNC TURNING FOR BRIGHT BAR (EN24T STEEL) BY TAGUCHI METHOD

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ABSTRACT

In actual machining, there are many factors which affect the surface roughness and material removal rate i.e. cutting conditions, tool variables and work piece variables. Cutting conditions include speed, feed and depth of cut and also tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and work piece variable include hardness of material and mechanical properties. It is very difficult to take all the parameters that control the surface roughness for a particular manufacturing process.

This experimental investigation examines the effect of process parameters (Spindle speed, feed rate, and depth of cut) on SR and MRR during machining on CNC lathe.

An orthogonal array constructed to find optimal level of process parameters and to analyse effect of this parameters. S/N ratio has been calculated to construct ANNOVA table by using Minitab 17 to study performance characteristics in dry conditions. Result shows the depth of cut is most significant factor for producing minimum SR and maximum MRR .The optimal value of the surface roughness comes out to be 3.08 µm and for material removal rate it comes out 3363.93 mm^3/min. The optimal results have been verified through confirmation test also regression analysis has been performed to find out the relationship between input factors with surface roughness and material removal rate.

KEYWORDS: CNC Turning, Taguchi method, ANNOVA, SR, MRR.

INTRODUCTION

Turning is the machining process used to generate external cylindrical forms by removing material, usually with a single-point cutting tool. The cutting tool operates directly on the work piece during a machining operation, it affects the texture of the work piece surface which in turn provides reliable and detectable information to categorize the condition of the tool. Consequently, a machined surface is a replica of the cutting edge which carries valuable information related to the tool condition (i.e., sharpness or bluntness).

The surface texture of an engineering component was very important. It was affected by the machining processes by changes in the conditions of either the component or machine. A machined surface carries a lot of valuable information about the process including tool wear, built-up edge, vibrations, damaged machine elements etc. Under stable machining conditions, the surface texture changes remarkably due to the changes in the cutting tool shape caused by wear.

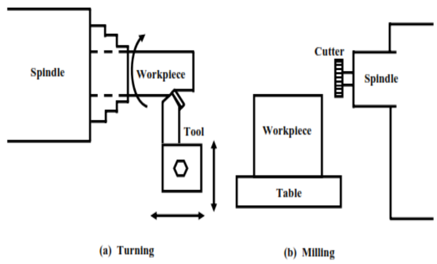

Figure 1.1 Drives in metal cutting

The material removal rate, MRR, can be defined as the volume of material removed divided by the machining time. Another way to define MRR is to imagine an "instantaneous" material removal rate as the rate at which the cross-section area of material being removed moves through the work piece. Since the depth of cut is changing the material removal rate changes continuously during the process.

The purpose of this project work is to investigate the surface roughness and material removal rate of engineering components by turning process. To achieve the result of surface roughness and material removal rate, the material used for the investigation is Bright bar (EN24T steel). Thus, the surface roughness and material removal rate is planned to be measured and observed in the experiment. The Taguchi method is used to design the variables of cutting parameter in the experiment in order to obtained data of various specimens. Optimization was involved in the research to provide a better surface roughness and to increase material removal rate predictions for turning mild steel. Taguchi has proposed off line for quality improvement in place of an attempt to inspect quality in the product on the product line. Taguchi has recommended three stage processes to achieve the desirable product quality by design. They are:

1). System Design

2). Parameter Design and

3). Tolerance Design.

LITERATURE

Sujit Kumar Jha, et al.[1] research has demonstrated an application of the Taguchi method for investing the effects of cutting parameters on material removal rate in turning aluminium metal. With analysis of results in this work using S/N ratio approach and ANOVA provides a systematic and efficient methodology for the optimization of cutting parameters.

Aditya Kulkarni, et al. [2] studied optimization of power consumption using Taguchi"s technique. Taguchi approach is used in this study to optimize CNC turning of AISI 1040 steel for power consumption by considering input parameter as cutting speed, feed, and depth of cut, nose radius and cutting fluid concentration. The following conclusions can be deduced from the findings of this study:

ANOVA result shows that cutting speed (48.15%), depth of cut (24.99%) and cutting fluid concentration (12.13%) has physical as well as statistical influence on power consumption.

Upinder Kumar Yadav, et al. [3] done experimental investigation And Optimization of Machining Parameters for Surface Roughness in CNC Turning by Taguchi Method and conclude following results . The Surface roughness is mainly affected by feed rate and cutting speed. With the increase in feed rate the surface roughness also increases & as the cutting speed decreases the surface roughness increases. From ANOVA analysis, parameters making significant effect on surface roughness are feed rate and cutting speed.

Mr.Pankaj Sharma, et al. [4] investigated Multi-Response Optimization by Experimental Investigation of Machining Parameters in CNC Turning by Taguchi Based Grey Relational and found Grey relational based Taguchi method was applied for the multiple performance characteristics of turning operations. A grey relational analysis of the Material removal rate and the surface roughness obtained from the Taguchi method reduced from the multiple performance characteristics to a single performance characteristic which is called the grey relational grade.

Mr. Harish Kumar, et al. [5] Experimentally verify that the Taguchi approach gives us the optimal parameters in the CNC turning process using High Speed Steel cutting tools the optimum set of speed, feed rate and depth of cut and the most affecting parameters having the impact of 59.9% is Speed.

Mrs. Poornima, et al. [6] investigated anddetailed study and the optimization procedure has been made to study the effect of speed, feed and depth of cut while machining which would help in real practice. The results obtained from RSM are R-Sq obtained was 99.9% which indicates that selected parameters (speed, feed, depth of cut) significantly affect the response (surface roughness).

PROBLEM DEFINITION

The machining parameters such as cutting speed, feed rate, depth of cut, features of tools, work piece material and coolant conditions were highly affect the performance characteristics. It was necessary to select the most appropriate machining settings in order to improve cutting efficiency, lower the process cost, and produce high-quality components.

a) What is the relationship between the controllable factors (in the study: spindle speed, feed rate, and depth of cut) and the response factor (surface roughness and material removal rate)?

b) What are the significant controllable factors that produce a better surface finish and increase material removal rate?

DESIGN OF EXPERIMENTS

An outline of the recommended procedure of an experimental design is briefly explained below,

1. Statement of the experimental problem..
2. Understanding of the present situation..
3. Choice of response variables.
4. Choice of factors and levels.
5. Selection of experimental design procedure.
6. Performing the experiments.
7. Data analysis.
8. Analysis of the results and conclusions. 9. Confirmation test.
10.Recommendations and follow-up management.
11. Planning of subsequent experiments.

Classification of Experimental Designs

1. Factorial design
2. Fractional factorial design

The Taguchi System Of Quality Engineering

Dr. Genichi Taguchi has introduced more cost effective engineering methodology namely robust design to deliver high quality products at low cost through research and development. It can greatly improve an organization's ability to meet market windows, keep development and manufacturing costs as low as possible. Robust design uses any ideas from statistical experiment design and adds a new dimension to it by explicitly addressing two major concerns faced by all products and process designers:

- How to reduce economically the variation of a product's function in the customer's environment?
- How to ensure that decisions found optimum during laboratory experiments will prove to be valid and reliable in manufacturing and customer environments?

The major steps of implementing the Taguchi method are:

(1) to identify the factors/interactions,
(2) to identify the levels of each factor,
(3) to select an appropriate orthogonal array (OA),
(4) to assign the factors/interactions to columns of the OA,
(5) to conduct the experiments,
(6) to analyse the data and determine the optimal levels, and
(7) to conduct the confirmation experiment.

In the field of communication engineering a quantity called the signal-to-noise (SN) ratio has been used as the quality characteristic of choice. Taguchi, whose background is communication and electronic engineering, introduced this same concept into the design of experiments. There are several SN ratios available depending on the type of characteristic:

1) Nominal is Best Characteristics
2) Smaller the Better Characteristics
3) Larger the Better Characteristics

ORTHOGONAL ARRAYS:

Many designed experiments use matrices called orthogonal arrays for determining which combinations of factor levels to use for each experimental run and for analysing the data. In the past, orthogonal arrays were known as 'magic squares' Perhaps the effectiveness of orthogonal arrays in experimental design is magic.

EXPERIMENTAL PROCEDURE AND RESULTS ANALYSIS

EXPERIMENTAL PROCEDURE

The turning operation is carried out on the CNC Lathe machine for the better accuracy of Result. single point cutting tool. Inserts of Sandvik GC4035 (HC) – P35 (P20 — P45) CVD-coated carbide grade for roughing and finishing of steel and steel castings under unfavourable conditions are used.

Figure.5.1 CNC Turning Lathe Machine

WORK PIECE MATERIAL FOR EXPERIMENTATION:

EN24T grade is a nickel chromium molybdenum specification usually supplied hardened and tempered as EN24T or EN24U. EN24T steel is composed of (in weight percentage) Carbon 0.35-0.45% Silicon 0.10-0.35% Nickel 1.30-1.80% Manganese 0.45-0.70% Chromium 0.90-1.40% Phosphorous 0.05% max Molybdenum 0.20-0.35% Sulphur 0.05% max.

Condition	Tensile N/mm^2	Yield N/mm^2	Elongation %	Izod KCV J	Hardness Brinell
T	850-1000	650	13	35	248-302

SELECTION OF PROCESS PARAMETERS AND THEIR LEVELS

The level of parameters is the main point because it will affect the surface finish and material removal rate of the work piece. It is important task to select a good combination of parameters level for achieving high cutting performance. The experimentation for this study was based on Taguchi"s design of experiments (DOE) and orthogonal array. Based on the literature review, in present investigation three levels are defined for each of the identified factor as shown in Table.

Para / Levels	CUTTING SPEED (RPM)	FEED (MM/REV)	DEPTH OF CUT (MM)
LEVEL 1	600	0.10	0.4
LEVEL 2	800	0.15	0.8
LEVEL3	1000	0.20	1.2

Work piece preparation and Inspection:

Raw material of Ø25 mm was first turned on manual lathe with depth of cut 1mm and made Ø24, then on CNC machine 27 no. of components were made with desired combination of speed, feed, and depth of cut. Fig 5.6.shows work pieces finished on CNC lathe.

Surface roughness of the machined work piece at three different spot was measured using Mitutoyo SJ 201 surface roughness tester (Fig.) and mean of the result is investigated for the experimentation.

Observation Table for Surface Roughness and S/N Ratio and Mean Correlations: The results of Taguchi experiments are then transformed into a signal to noise (S/N) ratio to measure the deviation of the performance characteristics from the desired values. For SR desired characteristics is smaller is better, the desired characteristic for material removal rate is larger is better.

Sr. No.	Speed	Feed	DOC	SR	Mean SNRA	Mea n SR
1	600	0.1	0.4	3.07	-9.77	3.08
2	600	0.1	0.4	3.18		
3	600	0.1	0.4	2.98		
4	600	0.15	0.8	5.50	-13.9	4.96
5	600	0.15	0.8	5.27		
6	600	0.15	0.8	4.12		
7	600	0.2	1.2	11.19	-21.1	11.38
8	600	0.2	1.2	12.94		
9	600	0.2	1.2	10.02		
10	800	0.1	0.8	4.06	-13.3	4.59
11	800	0.1	0.8	4.29		
12	800	0.1	0.8	5.43		
13	800	0.15	1.2	5.78	-16.4	6.62
14	800	0.15	1.2	7.38		
15	800	0.15	1.2	6.71		

16	800	0.2	0.4	6.99	-15.3	5.77
17	800	0.2	0.4	5.41		
18	800	0.2	0.4	4.92		
19	1000	0.1	1.2	9.04	-18.6	8.51
20	1000	0.1	1.2	9.09		
21	1000	0.1	1.2	7.42		
22	1000	0.15	0.4	4.50	-13.7	4.85
23	1000	0.15	0.4	5.11		
24	1000	0.15	0.4	4.95		
25	1000	0.2	0.8	5.15	-14.1	5.10
26	1000	0.2	0.8	4.58		
27	1000	0.2	0.8	5.57		

EFFECT OF INPUT PARMETERS ON SURFACE ROUGHNESS

Taguchi Analysis: S/F versus SPEED, FEED, DOC

Smaller is better

Level	SPEED	FEED	DOC
1	**-14.98**	**-13.91**	**-12.95**
2	-15.04	-14.73	-13.83
3	-15.52	-16.9	-18.76
Delta	0.54	2.98	5.82
Rank	3	2	1

Table 5.6. Response Table for Signal to Noise Ratios (SR)

Level	SPEED	FEED	DOC
1	6.477	**5.399**	**4.57**
2	**5.666**	5.483	4.89
3	6.16	7.421	8.843
Delta	0.811	2.023	4.274
Rank	3	2	1

Table: Response Table for Means (SR)

The ranks and the delta values in above table shows that DOC have greatest effect on SR and is followed by feed and speed in that order. As SR is ' smaller the better' type quality characteristics from main effect plot (Fig. 5.8) it can be seen that that first level of cutting speed A1=600rpm ,first level of feed B1=0.10mm and first level of DOC C1= 0.4mm provide minimum SR. **(A1-B1-C1)**

Residual plots for surface roughness (a) Normal probability plot of residuals for tangential force data (b) Plot of residuals vs. fitted values for tangential force (c) Plot of residuals vs. the Frequency histogram and (d) Residuals vs. the order of the data shown in Figures. It can be seen in Figures. that all the points on the normal plot lie close to the straight line (mean line). This implies that the data is fairly normal and a little deviation from the normality is observed. It is noticed that the residuals fall on a straight line, which implies that errors are normally distributed. In addition, Figures (b), (c) and (d) revealed that there is no noticeable pattern or unusual structure present in the data. The histogram plot indicates a mild tendency for the non-normality; however the normal probability plots of these residuals do not reveal any abnormality. Residual versus fitted value and residual versus observation order plot do not indicate any undesirable effect.

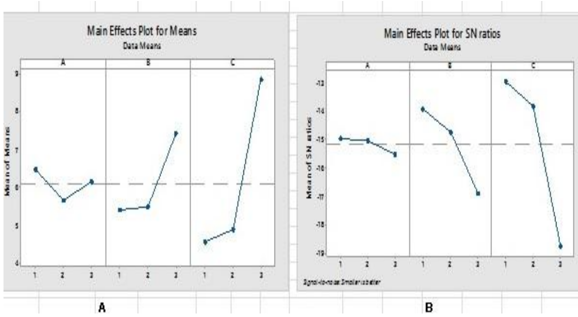

Fig. Main effect plot

Residual Plots For Surface Roughness

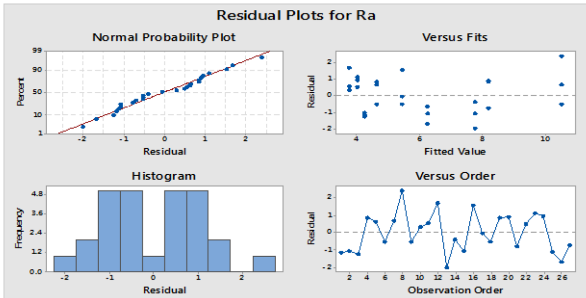

Fig. Residual plots for surface roughness (a) normal probability plot of residuals for surface roughness data, (b) plot of residuals vs. fitted values for surface roughness, (c) plot of residuals vs. the histogram, (d) residuals vs. the order of the data.

Predictive Equation and Verification:

The predicted values Ra at the optimal levels are calculated by using the relation:

$$ň = \sum_{i=0}^{0} (nim - nm)$$

where,

ň =Predictable Value

nm = Total mean value of SR

nim = Mean SR at optimum level of each parameter

o =No. of main machining parameters that affect the response parameter

Applying this relation, predicted values of MRR and Ra at the optimum conditions are calculated as:

ñRa = 6.101 + [(5.666 – 6.101) + (5.399 – 6.101) + (4.57 – 6.1010)]= **3.433 µm**.

5.13.1 Verifications:

1. For Surface Roughness (Ra) the response at the optimum condition (A1-B1-C1) calculated value of surface finish is 3.08 µm. The error in the predicted optimum value (3.433) and experimental value (3.08) is negative hence less than 0%.

Regression analysis was carried out to ensure a least squared fitting to error surface in Minitab 17 environment. The general first order model was developed to predict the SR over the experimental region (equation 1&2).

SR = -0.57 - 0.00079 SPEED + 20.23 FEED + 5.342 DOC -------------------------- (1)

CONCLUSIONS

The conclusions of this study may be summarized as follows:

1. From the above experimental investigation it has been found that depth of cut is the most significant factor for surface roughness and material removal rate .The contribution of depth of cut towards surface roughness is 79.33% .

2. It is found that the parameter of the Taguchi method provides a simple, systematic & efficient methodology for the optimization of the machining parameters.

3. Regression analysis has been perform to find out the relationship between input factors (speed, feed rate, and depth of cut) and responses using Minitab 17.

FUTURE SCOPE

1. Use of coolant with variants can be proposed for further study.
2. Other popular materials can be included in the study e.g. – Stainless Steel grades with higher hardness

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