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Research Paper

OPTIMIZATION OF CNC TURNING PROCESS PARAMETERS FOR PREDICTION OF SURFACE ROUGHNESS THROUGH TAGUCHI'S PARAMETRIC DESIGN APPROACH

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Metal cutting operations still represent the largest class of manufacturing operations where turning is the most commonly employed material removal process and there are lots of studies to investigate this complex process in both academic and industrial world. Predicting the better cutting condition during turning is of great importance as it helps in getting the Surfaces quality before machining starts. The major indication of surfaces quality on machined parts is surface roughness. Again, optimization of cutting parameters is one of the most important elements in any process planning of metal parts as economy of machining operation plays a key role in gaining competitive advantage. This paper presents an experimental study of main cutting condition in turning of SAE 8822 Alloy steel work and finding the influence of turning parameters during turning. For experimentation over this proposed work, a CNC turning centre would be engaged for machining the SAE 8822 Alloy steel work piece material with carbide cutting tool insert with a set of values for the given parameters. The experimentation is carried out considering three machining parameters: cutting speed, feed rate and depth of cut as independent variables. Design of Experiment (DOE) with Taguchi L9 Orthogonal Array (OA) is used for finding the optimized solution. An attempt has been made to find the influence of turning parameters speed, feed, and depth of cut using Analysis of Variance (ANOVA). Finally, the ranges for best cutting conditions are proposed for serial industrial production.

Keywords: Optimisation, CNC turning, Surface roughness, Taguchi orthogonal array, ANOVA

INTRODUCTION

The selection of proper combination of machining parameters yields the desired surface finish, the proper combination of machining parameters is an important task as it determines the optimal values of surface

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roughness. The new methodologies and standards are emerging day by day in reducing the lead time in the fabrication of a new product with good precision and high reliability. Advances in CNC/NC machining and high speed machining technologies have boosted the productivity of machining process.

The study of most important variables effecting the quality characteristics and a plan for conducting such experiments is called Design of Experiments (DOE). In the present work a set of experiments are conducted on the work piece SAE 8822 Alloy steel with carbide cutting tool insert to evaluate the effect of machining parameters such as speed, feed, and depth of cut on surface roughness. Taguchi approach is used to obtain the optimal settings of these process parameters, and ANOVA is used to analyze the influence of the cutting parameters during machining.

The general specification of coated cemented carbide insert is CNMA 120408 KBM10B. Cemented carbides are very effective in machining cast irons and certain abrasive non-ferrous alloys, but as such are good for Cutting steels because wear craters are developed on the face of the tool.

PLAN OF INVESTIGATION

This investigation was planned to be carried out in following steps

- Identifying the process parameters.
- Selection of the useful limits of the cutting parameters, namely speed (v), feed (f), and depth of cut (doc).
- Developing the design matrix.
- Conducting the experiment as per Taguchi design matrix.
- Testing the significance of regression co-efficient and arriving at the final form of the mathematical models.
- Presenting the main effects and the significant interactions between different parameters in graphical forms.
- Analysis of results and conclusions.

METHODOLOGY

In this work, experimental results were used for Optimization of input machining parameters speed, feed, and depth of cut using Taguchi Technique for the response Surface Roughness. ANOVA is also used for Predicting the influence of various parameters on Ra.

Taguchi Method

Competitive crisis in manufacturing during the 1970s and 1980s that gave rise to the modern quality movement, leading to the introduction of Taguchi methods to the US in the 1980s. Taguchi's method is a system of design engineering to increase quality. Taguchi Methods refers to a collection of principles which make up the framework of a continually evolving approach to quality. Taguchi Methods of Quality Engineering design is built around three integral elements, the loss function, signal-to-noise ratio, and orthogonal arrays, which are each closely related to the definition of quality. Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipment, and facilities. These improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best results. Taguchi proposed a standard procedure for applying his method for optimizing any process.

The objective of the robust design is to find the controllable process parameter settings for which noise or variation has a minimal effect on the product's or process's functional characteristics. It is to be noted that the aim is not to find the parameter settings for the uncontrollable noise variables, but the controllable design variables. To attain this objective, the control parameters, also known as inner array variables, are systematically varied as stipulated by the inner orthogonal array. For each experiment of the inner array, a series of new experiments are conducted by varying the level settings of the uncontrollable noise variables. The level combinations of noise variables are done using the outer orthogonal array.

The influence of noise on the performance characteristics can be found using the ratio. Where S is the standard deviation of the performance parameters for each inner array experiment and N is the total number of experiment in the outer orthogonal array. This ratio indicates the functional variation due to noise. Using this result, it is possible to predict which control parameter settings will make the process insensitive to noise. Taguchi method focuses on Robust Design through use of

- Signal-to-noise ratio
- Orthogonal arrays

Orthogonal Arrays

An orthogonal array is a type of experiment where the columns for the independent variables are "orthogonal" to one another. Orthogonal arrays are employed to study the effect of several control factors. Orthogonal arrays are used to investigate quality. Orthogonal arrays are not unique to Taguchi. They were discovered considerably earlier (Bendell, 1998). However Taguchi has simplified their use by providing tabulated sets of standard orthogonal arrays and corresponding linear graphs to fit specific projects (Taguchi and Kenishi, 1987; and ASI, 1989). A L9 Orthogonal array is shown in the Table 2

Table 1: Process Parameters and Their Levels

Level	Spindle Speed (s) (rpm)	Feed Rate (f) (mm/rev)	Depth of Cut (doc) (mm)
1	2557	0.06	0.6
2	2041	0.11	0.9
3	1693	1.27	1.2

Table 2: Orthogonal Array (OA)

S. No.	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
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

Selection of Orthogonal Array

To select an appropriate orthogonal array for the experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between design parameters that need to be made to determine which level is better and

Table 3: Orthogonal Array with Process Parameters

S. No.	Speed s (rpm)	Feed f (mm/rev)	Depth of Cut doc (mm)
1.	2557	0.06	0.6
2.	2557	0.11	0.9
3.	2557	1.27	1.2
4.	2041	0.06	0.9
5.	2041	0.11	1.2
6.	2041	1.27	0.6
7.	1693	0.06	1.2
8.	1693	0.11	0.6
9.	1693	1.27	0.9

specifically how much better it is. For example, a three-level design parameter counts for two degrees of freedom. The degrees of freedom associated with the interaction between two design parameters are given by the product of the degrees of freedom for the two design parameters.

Signal-to-Noise Ratio

The signal-to-noise concept is closely related to the robustness of a product design. A Robust Design or product delivers strong „signal . It performs its expected function and can cope with variations ("noise"), both internal and external. In signal-to-Noise Ratio, signal represents the desirable value and noise represents the undesirable value.

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems.

1. Smaller-the-Better S/N = –10 log $\left(\frac{1}{r}\sum_{i=1}^{r} y_i^2\right)$

2. Larger-The-Better S/N = –10 log $\left(\frac{1}{r}\sum_{i=1}^{r} \frac{1}{y_i^2}\right)$

3. Nominal-The-Best S/N = –10 log $\left(\frac{«^2}{±^2}\right)$

Analysis of Variance (ANOVA)

The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic. This is to accomplished by separating the total variability of the S/N ratios, which is measured by the sum of the squared deviations from the total mean S/N ratio, into contributions by each of the design parameters and the error. Various terms in ANOVA are

- Sum of squares (SS)
- Mean Squares (MS)
- Percentage contribution

EXPERIMENTAL WORK

The work piece material selected for investigation is the SAE 8822. The chemical and mechanical properties of the work piece are shown in Tables 4 and 5 respectively.

The cutting experiments were carried out on Work piece by CNC Lathe under different cutting conditions are shown in Table 3. Experimental data of SAE 8822 Steel which was used in experiments as shown in the Table

Figure 1: Experimental Set Up

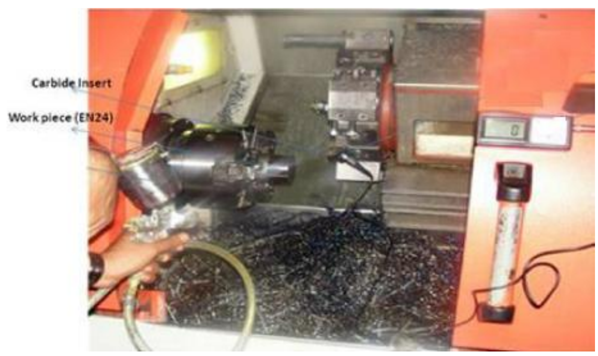

Table 4: Chemical Composition of SAE 8822 Alloy Steel

Element	C	Si	Mn	P	S	Cr	Ni	Mo
Content (%)	0.25	0.30	0.85	0.035	0.04	0.4	0.5	0.35

Table 5: Mechanical Properties of SAE 8822 Alloy Steel

Property	Density	Elastic Modulus	Poissons Ratio	Hardness (BHN)
Metric	7.79 g/cm^3	207 Gpa	0.30	245

Table 6: Experimental Data for 3 Parameters on Ra, for Carbide Tool

S. No.	Speed S (rpm)	Feed, f (mm/rev)	Depth of Cut (mm)	Surface Roughness Ra («m)
1.	2557	0.06	0.6	0.53
2.	2557	0.11	0.9	1.71
3.	2557	1.27	1.2	2.14
4.	2041	0.06	0.9	0.44
5.	2041	0.11	1.2	1.32
6.	2041	1.27	0.6	2.16
7.	1693	0.06	1.2	0.02
8.	1693	0.11	0.6	1.33
9.	1693	1.27	0.9	2.21

3. Tool material for this study was coated cemented carbide insert. Taguchi parameter optimization method was used to evaluate the best possible combination for minimum surface roughness during turning operation.

RESULTS AND DISCUSSION

In the Taguchi method the results of the experiments are analyzed to achieve one or more of the following three objectives:

- To establish the best or the optimum condition for a product or a process.
- To estimate the contribution of individual factors.
- To estimate the response under the optimum conditions.

Studying the main effects of each of the factors identifies the optimum condition (Figures 2 and 3). The process involves minor arithmetic manipulation of the numerical result and usually can be done with the help of a simple calculator. The main effects indicate the general trend of the influence of the factors. Knowing the characteristic, i.e., whether a higher or lower value produces the preferred result, the levels of the factors, which are expected to produce the best results, can be predicted.

The knowledge of the contribution of individual factors is the key to deciding the nature of the control to be established on a production process. The analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiment to determine the percent contribution of each factor. Study of the ANOVA table for a given analysis helps to

Figure 2: Plots of Main Effects for Means for Surface Roughness (Ra)

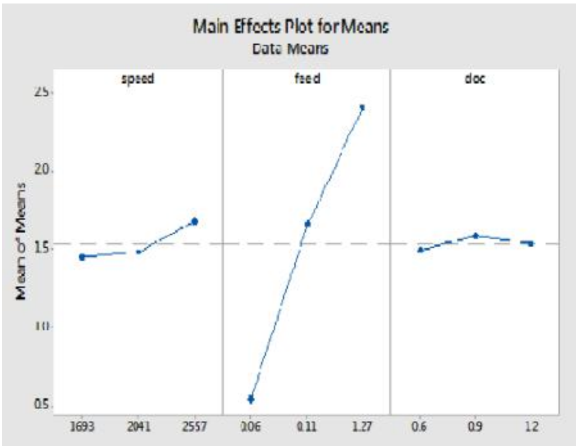

Figure 3: S/N Ratio for Surface Roughness (Ra)

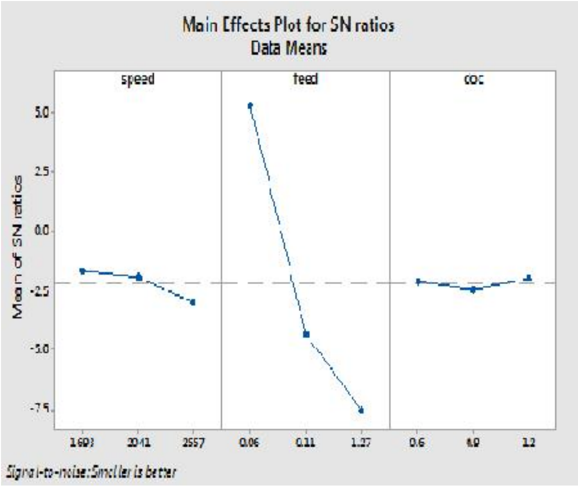

Table 7: Response Table for Signal to Noise Ratios for Carbide Tool [Ra]

Level	Speed (S)	Feed (f)	Depth of Cut (d)
1	–1.553	5.533	–2.177
2	–1.87	–4.422	–3.433
3	–2.380	–6.588	–2.001
Delta (maxmin)	1.296	11.207	0.511
Rank	2	1	3

Table 8: Response Table for Means for Carbide Tool [Ra]

Level	Speed (S)	Feed (f)	Depth of Cut (d)
1	1.55232	0.6003	1.4015
2	1.4904	1.5051	1.9211
3	1.6499	2.3999	1.0241
Delta (maxmin)	0.2466	1.9021	0.0835
Rank	2	1	3

determine which of the factors need control and which do not. In this study, an L9 Orthogonal array with was used. Response tables for Noise ratios and means are shown in Tables 7 and 8.

CONCLUSION

The results obtained in this study lead to conclusions for turning of EN 24 after conducting the experiments and analyzing the resulting data.

- From the results obtained by experiment, the influence of surface roughness (Ra) is depend on feed and next is followed by speed and depth of cut.
- Taguchi method is applied for optimization of cutting parameters.

FUTURE SCOPE OF THE WORK

- The work can be extended for Multi objective optimization like Material Removal Rate, Power Consumption, Tool life, Production cost and Production time.
- The use of ANN, Genetic algorithms, which have the ability to adapt to the problem being solved and are suggested by the evolutionary process of nature selection.
- The effect of tool Vibration, Work piece hardness, Cutting fluid, Nose radius, Tool material and Acoustic emission can be considered as cutting parameters as they have great influence on Surface roughness.

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