IJRAME
ISSN (ONLINE): 2321-3051
INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING

STUDY OF SURFACE ROUGHNESS IN TURNING OF AISI1050 MILD STEEL

Hemant Kumar Agarwal

Assistant Professor,VIET, Dadri ,Mail Id: resume.hka@gmail.com

Abstract

In this study the Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, S/N ratio, and ANOVA are used to study the performance characteristics in turning operations of AISI 1050 steel bars using uncoated tools. Three cutting parameters namely spindle speed, feed rate and depth of cut are optimized with considerations of surface roughness. Experimental results are provided to illustrate the effectiveness of this approach.

Keywords: Turning; signal to noise ratio; ANOVA.

1. INTRODUCTION

[1] Metal cutting technology, or more specifically the machining technology, is part and parcel of any mechanical manufacturing facility. It is also considered as the most commonly employed metal shaping process. Among the various machining operations, turning operation is one of the most widely and commonly used cutting operation carried on a lathe machine. A lathe machine in various and different forms have been in exercise for about more than 2000 years.

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.

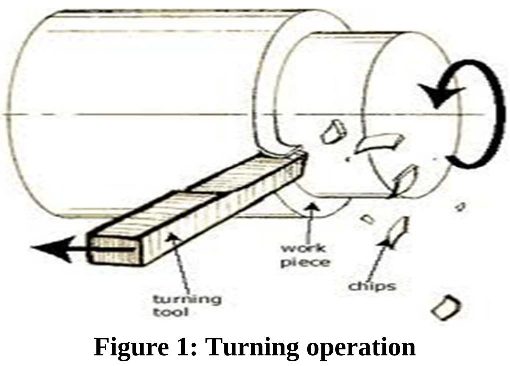


Figure 1: Turning operation

Surface roughness is a measure of the technological quality of a product and a factor that greatly influences manufacturing cost. It describes the geometry of the machined surface.

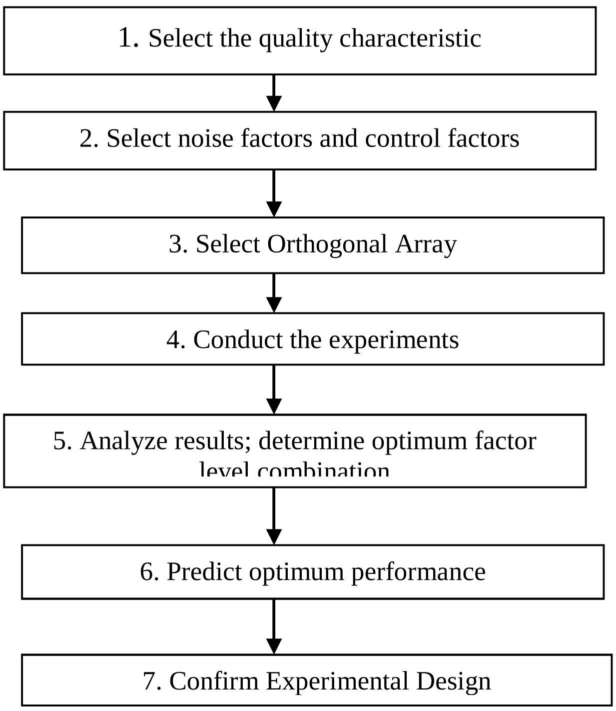
Vol.2 Issue.1,
January 2014.
Pgs: 105-111

There were two purposes of this research. [3-6] The first was to demonstrate a systematic procedure of using Taguchi parameter design. The second was to demonstrate a use of Taguchi parameter design in order to identify the optimum surface roughness performance with a particular combination of cutting parameters in a turning operation.

The paper is organised in the following manner. An overview of the parameter design based on the Taguchi method is given first. Then the parameter design with the multiple performance characteristics is introduced. After that , the experimental detail of using the parameter design to determine and analyse the optimum cutting parameters is described. At last, the paper concludes with a summary of this study.

2. Taguchi method

[2] Sir R. A. Fisher introduced the Design of Experiments (DOE), a statistical method, in the early 1920 in England [1]. He used this technique, DOE, to find out the optimum rain, water, soil and fertilizer conditions required to get best crop turn out. By means of the DOE method, Fisher was intelligent enough to write down all combinations (also known as trials or treatment conditions) of the parameters considered in investigational study. Using a matrix design, the conditions were generated which permitted each parameter to contribute evenly in test conditions. He also introduced techniques for analysing the outcomes of each experiment. Methods were developed to carry out a fraction of the total experiments if the number of total combination turned out to be very large. Sir R. A. fisher developed the first technique that made it feasible to analyse the effect of more than one varying parameters at a time. After the introduction of DOE by Fisher in agricultural experimentation, much more development and research followed in this area. Unluckily, most of its utilization remained in the academic sector. Although, in industrial environment, the requirement to analyse the effect of more than one parameter is extensive, not a lot of industries other than a fraction of fertilizer and chemical industries have employed this technique in their manufacturing processes. Indeed, as academic environment matured, the more it acquired from a technique that manufacturing or process industries could apply and absorb. The more complicated the theory advocating DOE became, the less alluring it appeared to practicing scientists and engineers.
To summarize, the parameter design of the Taguchi methods includes the following steps:



Step 1. Selection of the quality characteristic

There are three types of quality characteristics in the Taguchi methodology, such as smaller-the-better, largerthe- better, and nominal-the-best. For example, smaller-the-better is considered when

Vol.2 Issue.1, January 2014. Pgs: 105-111

measuring fuel consumption of an automobile or shrinkage of a plastic component (Antony & Kaye, 1999). The goal of this research was to produce minimum surface roughness (Ra) in an end-milling operation. Smaller Ra values represent better or improved surface roughness. Therefore, a smaller-the-better quality characteristic was implemented and introduced in this study.

Step 2. Selection of noise factors and control factors

In the previous studies, Savage (1998) and Chen & Lou (2000) indicated that depth of cut, cutting speed, and feed rate had significant effects on surface roughness in the end milling operations. In this study, the controllable factors are depth of cut (A), cutting speed (B), feed rate (C), and tool diameter (D), which were selected because they can potentially affect surface roughness performance in end-milling operations. Since these factors are controllable in the machining process, they are considered as controllable factors in the study. One of the important attributes of Taguchi parameter design is it could also consider uncontrollable (Noise) factors in the analysis. One of the noise factors used in this study is the measurement location of the work piece. It is very difficult to control the surface roughness measurement because it is different at separate locations. In this study, the measurement location of the finished surface was considered as a noise factor and was measured at three different locations.

Step 3. Selection of Orthogonal Array

There are 18 basic types of standard Orthogonal Arrays (OA) in the Taguchi parameter design (Torng, Chou, & Liu, 1997). Since four factors were studied in this research, three levels of each factor were considered. Therefore, an L_{18} Orthogonal Array (L_{18} (21 x 37)) was selected for this study. Each run will have three data collected. Therefore, a total of (18*3) = 54 data values were collected, which were conducted for analysis in this study.

Step 4. Conducting the experiments

Figure 3 illustrates the experimental settings in this study for work piece and end-milling operations (Lou, Chen & Li, 1998). The tool used in this experiment was a four-flute, highspeed steel end mill. The material used for the experiment was one-inch-cubic blocks of 6061 aluminum. The 18 experiments, shown in Table 2, were randomly run by the CNC Fadal vertical milling machine. Also, three measured surface roughness data values were collected using the manual stylus type instrument to measure the finished work pieces after end milling was completed. After the data were collected and recorded in Table 3, signal-to-noise ratios of each experimental run were calculated based on the following equation, which are listed in Table 3 with the data. (3) where n = number of measurements in a trial/row, in this case, n=3 and *yi* is the *i*th measured value in a run/row. The average response values were also calculated and recorded.

Step 5. Analyzing the results and determining the optimum cutting conditions

(a) Analysis of Raw Data and S/N Ratios After raw data were collected (Table 3), average effect response values and S/N response ratios, were calculated. The calculation of average effect response values and S/N ratios were based on the following procedure. For example, the average effect for level one of depth of cut was computed using data from experimental numbers 1-3 and 10-12 of Table 3. The average effect for level two of depth of cut was computed using experimental numbers 4-6 and 13-15 of Table 3. The average effect for level three of depth of cut was computed using experimental numbers 7-9 and 16-18 of Table 3. Similarly, the average effect of cutting speed and feed rate was computed for all other cutting levels. The S/N ratio is calculated in the same way. The average effects and S/N ratios for each level of cutting parameters are summarized and referred to in the average effects response table and S/N ratios response table for surface roughness (Ra).

b) Analysis of Variance

The purpose of the analysis of variance (ANOVA) is to determine which cutting parameters significantly affect the quality characteristic (Ra). Table 6 shows the results of ANOVA analysis of raw data for surface roughness.

Step 6. Predicting Optimum Performance

Using the aforementioned data, one could predict the optimum surface roughness performance using the cutting conditions as:

Predicted Mean = $A2 + B3 + C1 + D2 - 3\cdot(y)$

Step 7. Establishing the design by using a confirmation experiment

The confirmation experiment is very important in parameter design, particularly when screening or small fractional factorial experiments are utilized. The purpose of the confirmation experiment in this study was to validate the optimum cutting conditions.

Quality can be perceived differently by different people. It is also different for different products, processes, or services under discussion. Even in strictly technical terms, quality can be performance, durability, reliability, delivery, shape, or size. For some products it might only be appearance, or service after delivery. Indeed, product quality, as perceived by the customer, can be one or more of the criteria mentioned. Taguchi has given us a practical definition of quality that can be applied to most products and processes around us. Taguchi proposed a mathematical formula called the loss function for estimating the monetary loss caused by lack of quality. The loss function estimates loss even if parts are made within specification limits. This is necessary to allow for the fact that a company that makes all parts within specification limits still has warranty and customer complaints. That is, there is some loss associated with a population of parts no matter how well they are produced.

3. Experimental procedure

a. Work piece material

The workpiece material selected for investigation is AISI 1050 mild steel. Its composition is given in Table 1. The size of the work piece is round in shape, 22 mm in diameter and 140 mm in length.

Table 1. Chemical properties of AISI 1050 mild steel

Element	C	Mn	Si	P	S	Ni	Cr	Mo	Cu
Weight (%)	0.16	0.538	0.177	0.026	0.018	0.036	0.062	0.004	0.059

b. Machining process

The turning process is carried out on medium duty TC 360X750 CNC lathe. . A tool holder with a specification PCLNR 2020K12 was used in this experiment. Carbide insert CNMG120408 MT coated with TiC was used in the cutting tool insert. The experiments were conducted as per orthogonal array and the surface roughness was measured using TR- 100 surface roughness tester.

c. Plan of experiments

The experiments were planned using Taguchi's orthogonal array in the design of experiments, which helps in reducing the no. of experiments. The experiments were conducted according to a 3 level L_9 orthogonal array.

Table 2. Cutting parameters and their levels

Symbol	Cutting parameters	Unit	Level 1	Level 2	Level3
A	Spindle speed	RPM	500	700	900
B	Feed rate	mm/rev.	0.1	0.2	0.3
C	Depth of cut	mm	0.1	0.2	0.3

4. Design and Analysis of cutting parameters

The results of the turning experiments were studied using S/N and ANOVA. Based on the results of the S/N and ANOVA, optimal cutting parameters for surface roughness were obtained and verified.

a. Analysis of S/N ratio

To obtain optimal cutting conditions, the lower the better quality characteristic for surface roughness has been taken.

$$\eta = -10\log\left(\frac{1}{m}\sum_{i=1}^{m} S_i^2\right)$$

Where S_i is the value of surface roughness for the i^{th} test.

Table 3 shows the experimental results for surface roughness and the corresponding S/N. The S/N response table is shown in table 4.

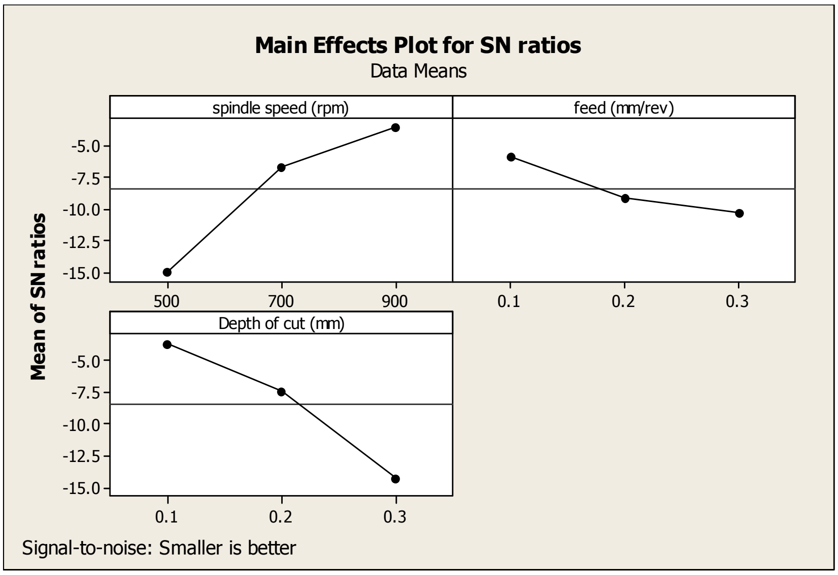
Table 3. Experimental results

Experiment no.	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Surface roughness (µm)	S/N ratio (dB)
1	500	0.1	0.1	2.185	-6.78903
2	500	0.1	0.2	6.275	-15.9523
3	500	0.1	0.3	12.997	-22.2769
4	700	0.2	0.3	1.385	-2.82900
5	700	0.2	0.2	4.179	-12.4214
6	700	0.2	0.1	1.788	-5.04735
7	900	0.3	0.3	2.54	-8.09667
8	900	0.3	0.1	0.9	0.915150
9	900	0.3	0.2	1.498	-3.51024

Table 4. Response Table for Signal to Noise Ratios for surface roughness

Level	**Spindle speed (rpm)**	**Feed (mm/rev)**	**Depth of cut (mm)**
1	-15.006	-5.905	-3.640

2	-6.766	-9.153	-7.431
3	-3.564	-10.278	-14.265
Delta	11.442	4.373	10.625
Rank	1	3	2



4.2 Analysis of variance

The purpose of Analysis of Variance is to investigate which of the given process parameters mainly affect the performance characteristic. This is accomplished by separating the total variability of the S/N ratios, which is measured by sum of square deviations from the total mean S/N ratio. First, the total sum of squared deviations SS_T from the total mean S/N ratio η_m can be calculated as

$$SS_T = \sum_{i=1}^{n} (\eta i - \eta m)2$$

Where n is the no. of experiments in the orthogonal array and η_i is the mean S/N ratio for the i^{th} experiment. There is a tool called F- test named after Fisher to identify the parameter that has significant effect on the quality characteristic. In general if F > 4, then it means that the change in design parameter has significant effect on quality characteristic. Table 5 shows the results of ANOVA for surface roughness.

Table 5. Results of ANOVA for surface roughness

Symbol	Cutting parameter	Degrees of freedom	Sum of squares	Mean square	F	P
A	Spindle speed	2	209.075	104.537	28.14	0.034
B	Feed rate	2	30.941	15.470	4.16	0.194
C	Depth of cut	2	173.957	86.978	23.41	0.041
Error		2	7.431	3.715		
Total		8	421.403			

4.3 Confirmation tests

Once the optimal level of the design parameters has been selected, the final step is to predict and verify the improvement of the quality characteristic using the optimal level of design parameters. The estimated S/N ratio η_e using the optimal level of design parameters is calculated as

$$\eta_e = \eta_m + \sum_{i=1}^{o} \eta_{im} - \eta_m$$

Where η_m is the total mean S/N ratio at the optimum level and o is the no. of main design parameters that affect the quality characteristic.

Table 6 shows the comparison of the predicted surface roughness with the actual surface roughness using optimal cutting parameters.

	Optimal cutting parameters	
	Prediction	**Experiment**
Level	A3B1C1	A3B1C1
Surface roughness	0.8	0.75
S/N ratio (dB)	3.80	1.20

5. Conclusions

In this study the Taguchi optimization method was used to find the optimal process parameters, which minimizes the surface roughness. Taguchi orthogonal array, S/N ratio, ANOVA were used for the optimization of cutting parameters. ANOVA results show that spindle speed, depth of cut and feed rate affects the surface roughness according to descending order.

References

[1] Childs T.; Maekawa K.; Obikawa T.; Yamane Y. 2000, “Introduction in: Metal Machining”, Theory and Applications; Arnold Publishers, London, pp.1-34.

[2] Ross J. Philip, “Taguchi Techniques for Quality Engineering”, Second edition, Tata McGraw Hill, 2013.

[3] Yang W.H. and Tarang Y.S., 1998, “Design of optimization of cutting parameters for turning operations based on Taguchi method”, Journal of materials processing technology, volume 84, pp. 122-129.

[4] Kirby Daniel E., 2006, “A parameter design study in a turning operation using Taguchi method”, The technology interface / fall.

[5] Mahapatra S.S., Patnaik Amar, Patnaik Kumar Prabina, July 2006, “Parametric analysis and optimization of cutting parameters for turning operations based on Taguchi method”, Proceddings of the international conference on global manufacturing and innovation, volume. 1.

[6] Aslan Ersan, Camuseu Necip, Birgoren Burak, Apr 2006, “Design optimization of cutting parameters when turning hardened AISI 4140 steel (63 HRC) with Al_2O_3 + TiCN mixed ceramic tool”, Materials and Design, volume 28, pp. 1618-1622.

A Brief Author Biography

1st Author Name – A brief biography including qualifications, research interests, and any other information that the author wishes to include. Biography should be less than 150 words.

2nd Author Name – A brief biography including qualifications, research interests, and any other information that the author wishes to include. Biography should be less than 150 words.