Optimization of End Milling Process Parameters on Surface Roughness of SS 420 by Taguchi Method

Inderjeet Singh[1] Dr. A.P.S. Sethi[2]
[1]M.Tech. Student [2]Professor & Head
[1,2]BBSBEC, Fatehgarh Sahib

Abstract— The present work in this paper depicts the influence of different milling parameters spindle speed, feed rate and depth of cut. This investigation deals with the machining of SS 420 to optimize the process parameters and to minimize the surface roughness. The L9 orthogonal array is designed using Taguchi technique with three levels of each process parameters. The cutting operation of job was done by solid end mill four-flute cutter. A total of nine experimental run were carried out. Finally signal-to-Noise (S/N) ratio, Analysis of variance (ANOVA) and different plots developed by MINITAB 15 software were employed to study the effect of input parameters on Surface roughness (SR) and presented in this paper.

Key words: End Milling, SS 420, SR, L-9, ANOVA

I. INTRODUCTION

Milling is the process of removing extra material from the work piece with a rotating multi-point cutting tool, called milling cutter. The machine tool employed for milling is called milling machine. Milling machines are basically classified as vertical or horizontal. The three primary factors in any basic milling operation are speed, feed and depth of cut. Other factors such as kind of material and type of tool materials have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine [7].In industries, the profit and quality are always desirable with shortest possible time. Therefore, it becomes very important to select the machining variables in such a manner that the required quality is maintained without sacrificing the cost/profit. Milling parameters such as coolant employment, speed, feed, depth of cut has very significant role on considered Responses MRR and Surface Roughness (*Ra*). Many researchers had worked in order to improve those responses. Additionally, design of experiments, Taguchi method is being implemented to refine the outcome of the researches being carried out. There are many methods for optimization Viz. full factorial design, Response surface method, Taguchi method, etc. But Taguchi method is one of the power full techniques amongst optimization which takes minimum number of experiment. [5]

A. Computer Numerical Control

The computer numerically controlled machines are widely used in industries, fully controlled with minimum human intervention, to increase the productivity and improve the quality of machined parts.CNC end milling is the most important milling operation, widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish along with flexibility and versatility **[8].** It is a unique adaption of the conventional milling process which uses an end mill tool for the machining process. Processing time is very low as compared to some of the conventional machining process. In present time the technology of CNC vertical milling machine has been improved significantly to meet the advance requirements in various manufacturing fields, especially in the precision metal cutting industry [3]. In modern industry, one of the trends is to manufacture low cost, high quality products in short time. Automated and flexible manufacturing are employed for that purpose.CNC machines are considered most suitable in flexible manufacturing system [6]. Due to the advances in machine tool, CNC, CAD/CAM, cutting tool and high speed machining technologies the volume and importance of milling have increased in key industries such as aerospace, aeronautical, biomedical, die and mold, automotive and component manufacturing [9].

B. Surface Roughness

In machining process, Surface finish is one of the most significant technical requirements of the customer. A reasonably good surface finish is desired to improve the tribological properties, fatigue strength, corrosion resistance and aesthetic appeal of the product. Nowadays, manufacturing industries especially concerned to dimensional accuracy and surface finish [9]. The factors affecting the surface roughness are the machining conditions work piece material and tool geometry. Therefore in order to obtain better surface finish of a milled product, the optimal machining parameters and tool geometry are to be selected [10]. Surface roughness has received serious attention for many years and it is a key process to assess the quality of a particular product. Surface roughness has an impact on the mechanical properties and it also affects other functional attributes of parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity etc. [7].

II. LITERATURE REVIEW

Literature review fills the gap and defines the problems thereby preparing a base for its solution.

Chahal M. studied the effect of spindle speed, feed rate and depth of cut on H-13 material using taguchi methodology L-9 orthogonal array and reached to a conclusion that high spindle speed, high depth of cut and low feed rate were the optimized parameter for surface roughness (SR) [1]. Naidu G. G. in this study, experiments are performed to find out the set of optimum values for the selected control factors in order to reduce surface roughness using Taguchi's robust design methodology and to develop the prediction models for surface roughness considering the control factors. Four control factors viz. cutting speed, feed rate, depth of cut and coolant flow are investigated at three different levels. The work piece material used is EN-31 steel alloy. Experiments are carried out using L9 (3^4) orthogonal array [7]. Chandna P. and Kumar D. in this present work analysis of different parameters of end milling to minimize the surface roughness for AISI D2 steel is done. D2 Steel is generally used for stamping or forming dies, punches, forming rolls, knives, slitters, shear blades, tools, scrap choppers, tyre shredders etc. The experiments have been performed as per the combination of levels of different process parameters suggested by L9 orthogonal array. Experimental investigation of the end milling of AISI D2 steel with carbide tool by varying feed, speed and depth of cut and the surface roughness has been measured using surface roughness tester. Analyses of variance have been performed for mean and signal-to-noise ratio to estimate the contribution of the different process parameters on the process [2].

SS 420 has been used as a present work material is a martensitic high carbon steel. Very few work have been done on this material for the optimization of input parameters in milling operation such as spindle speed , feed rate and depth of cut.

III. DESIGN OF EXPERIMENT

Design of experiments was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agriculture field Research Station in London, England. His initial experiments were concerned with determining the effect of various fertilizers on different plots of land. Fishers used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since that time the DOE has been widely accepted in agricultural as well as Engineering Science [9]. The high amount of experiments to be conducted can be lessened by using Taguchi's orthogonal arrays. In fact, they are tables where the design parameters are located at columns as factors and the combinations of parameter values are placed at the rows as levels. The levels of each factor are equally presented in the trails. Once the trails based on the rows are carried out, the deviations are investigated. ANOVA tables are compiled to determine the relative importance of the factors in the experiment and to estimate error variance by calculating various statistical values orthogonal arrays help facilitate studying many design parameters concurrently and can be employed to estimate the effects of each factor independently [4].

A. *Material Used*

In this work SS 420 grade has been used as a work piece material having hardness 29-30 HRc and carbide end mill is being used as the tool material. The chemical composition of the material is shown in the Table 1 given below.

C	Si	Mn	P	S	Cr
0.30	0.35	0.83	0.030	0.032	13.25

Table 1: Chemical Composition of SS 420

B. *Machine Used*

End milling operation was carried out on a SURYA VF 30 CNC VS in dry conditions. The CNC milling machine equipped with AC variable speed spindle motor up to 6000 rpm and 3.7KW motor power was used for this present experimental work. The set up is shown as.

Fig. 1: Machine

C. *Process Parameters Of End Milling*

The input parameters range selected for this experiment is shown in the table 2. The range for spindle speed as 1200 rpm, 1500 rpm, 1800 rpm; feed rate as 150 mm/min, 250 mm/min and 350 mm/min and for depth of cut range is 0.2mm, 0.4 mm and 0.6 mm.

D. *Experimental Procedure*

Factors	Level 1	Level 2	Level 3
Speed (rpm)	1200	1500	1800
Feed (mm/min)	150	250	350
Depth of cut (mm)	0.2	0.4	0.6

Table 2: Selected Factors and Levels

Experiment no.	Spindle speed (rpm)	Feed rate (mm/min)	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

Table 3: Standard L9 OA

Experiment no.	Spindle speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)
1	1200	150	0.2
2	1200	250	0.4
3	1200	350	0.6
4	1500	150	0.4
5	1500	250	0.6
6	1500	350	0.2
7	1800	150	0.6
8	1800	250	0.2
9	1800	350	0.4

Table 4: Parameter Design

Taguchi's designs aimed to allow greater understanding of variation than did many of the traditional designs. Taguchi contended that conventional sampling is inadequate here as there is no way of obtaining a random sample of future conditions. Taguchi projected extending experimentation with an outer array or orthogonal array should simulate the random atmosphere. In the present work the experiments have been performed on the combinations of levels of factors defined by L9 orthogonal array. Taguchi orthogonal array is designed with three levels of three milling parameters. Orthogonal array design of experiment has been found suitable in the present work. It considers three process parameters (without interaction) to be varied in three discrete levels. The experimental design has been shown in Table 4 [2].

E. Signal to Noise Ratio

- Calculation of the Signal to noise ratio (S/N) ratio depends on the experimental objective. [5]
- The signal to noise ratio provides a measure of the impact of noise factors on performance. The larger the S/N, the more robust the product is against noise. [5]

IV. RESULTS AND DISCUSSIONS

The experiments were conducted by using the parametric approach of the Taguchi's method. The effect of individual Milling process parameters, on the selected quality characteristics – surface roughness, has been discussed. The average value and S/N ratio of the response characteristics for each variable at different levels were calculated from experimental data. The main effects of process variables both for raw data and S/N data were plotted. The response curves (main effects) are used for examining the parametric effects on the response characteristics. The analysis of variance (ANOVA) of raw data is carried out to identify the significant variables and to quantify their effects on the response characteristics. The most favorable values of process variables in terms of mean response characteristics are established by analyzing the response curves and the ANOVA tables. **[5]**

A. Effect on Surface Roughness

Surface roughness data was collected using stylus method of measurement with MITUTOYO SJ-201P make surface roughness tester with an accuracy of 0.01µm after the end milling of the work piece. Surface Roughness basically depends upon the feed rate, spindle speed, tool diameter and depth of cut. It is important output characteristic in milling or every machining process because SR has direct relation with the quality. And quick and high production is the need of modern production system. In end milling, the cutter generally rotates on an axis vertical to the work piece. **[1]** S/N ratio was calculated based on the following equation:-

$$S/N\ (\eta) = -10\log\frac{1}{n}\sum_{i=1}^{n} y_i^2$$

S/N is the signal to noise ratio of ith term,
n= number of measurements in a trial/row, in this case, n=3 and Yi is the ith measured value in a run/row.

Experiment no.	Spindle speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)	Surface roughness (µm)	Mean R_a (µm)
1	1200	150	0.2	-4.24375	1.63
2	1200	250	0.4	-3.28706	1.46
3	1200	350	0.6	-7.27224	2.31
4	1500	150	0.4	1.83030	0.81
5	1500	250	0.6	-3.16725	1.44
6	1500	350	0.2	-3.40523	1.48
7	1800	150	0.6	2.85335	0.72
8	1800	250	0.2	-1.06157	1.13
9	1800	350	0.4	-2.27887	1.30

Table 5: Raw data of SR

B. Determination of Optimum Parameters

Figure 2 (a) shows three graphs, containing the plots between mean of signal to noise ratio data and control factors. Likewise Fig. 2(b) also contains the plots between mean of mean and the input parameters i.e. control factors. The objective of using the S/N ratio as a performance measurement is to develop products and processes insensitive to noise factors. The S/N ratio indicates the degree of the predictable performance of a product or process in the presence of noise factors. Process parameter settings with the highest S/N ratio always yield the optimum quality with minimum variance (Antony & Kaye, 1999). Consequently, the level that has a higher value determines the optimum level of each factor. [1]

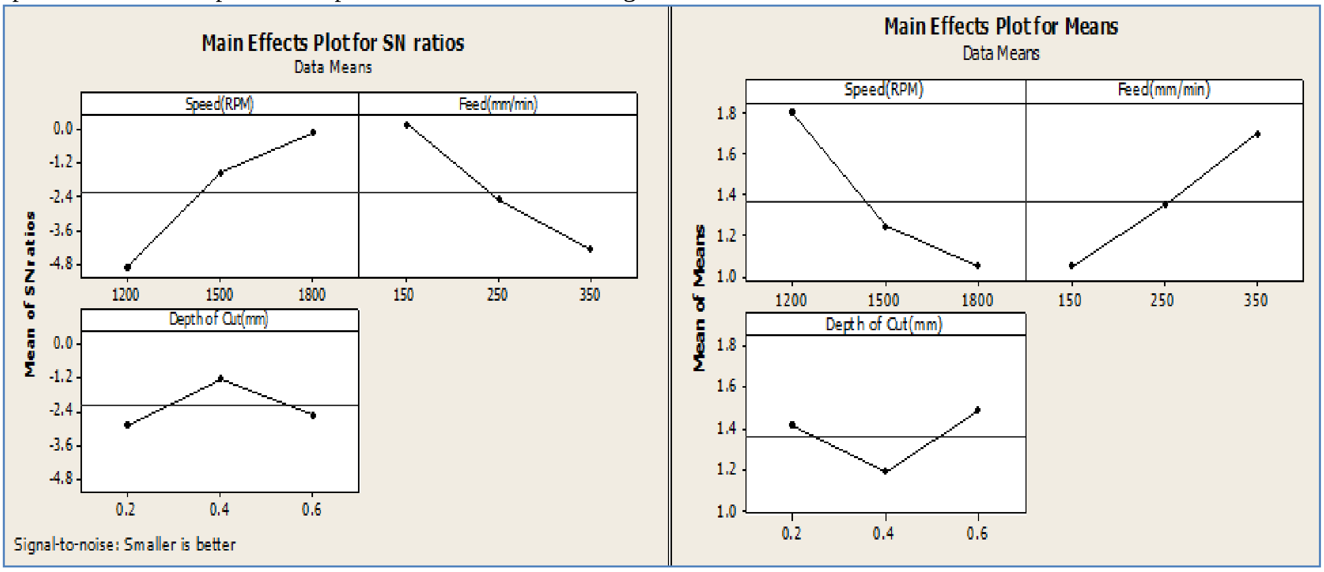

Fig. 2(a) Fig.2 (b)

Fig. 2: Graphs

In graph 2(a), the level three for spindle speed, (1800 rpm) level one for feed rate, (150 mm/min) and level two for depth of cut, (0.4 mm) has a higher value of S/N ratio value, which shows that these are the optimum values that produce minimum variation of the surface roughness. Similarly, level three for spindle speed i.e. 1800 rpm has indicated optimum value in term of mean value. Likewise level one of feed rate i.e. 150mm/min and level two of depth of cut i.e. 0.4 mm are the optimized values in term of mean values.

1) Effect of spindle speed on SR

It is seen that the SR is less at the third level of spindle speed (1800 rpm). As the spindle speed increases the surface roughness decreases.

2) Effect of feed rate on SR

With the increase in the feed rate, the SR increases. It is seen that the highest SR is obtained at the third level (350mm/min). Higher the feed rate lower the processing time thus increases the SR.

3) Effect of depth of cut SR

It is seen that the SR is minimum at the second level of depth of cut (0.4mm).

V. CONCLUSION

- Taguchi's robust design method is suitable to analyze the metal cutting problem as described in the present work.
- In end milling, increased spindle speed, increase in feed rate and increase in depth of cut will decreases the surface roughness within specified test range.
- In end milling, to obtained better surface finish for the specific test range the optimal combination of the cutting parameters is the set with A3, B1 and C2 i.e.1800 rpm, 150 mm/min and 0.4mm.

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