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Optimization of Milling Parameters for Minimum Surface Roughness Using Taguchi Method

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Abstract: *This study of optimization of milling parameters for minimum surface roughness uses Taguchi design application. Maintaining good surface quality involves additional cost or loss of productivity. Taguchi design is an efficient way to find optimum conditions of control factors in milling to obtain less surface roughness. The various control factors taken here are cutting speed, feed rate and depth of cut. An L_9 orthogonal array is used to fit the experimental values. Analysis is carried out to identify the significant factors affecting surface roughness, and the optimal cutting combination was determined by seeking the best surface roughness (response) and signal-to-noise ratio.*

Key words: *Taguchi method, Surface Roughness, End Milling, Orthogonal Array.*

I. Introduction

Milling operation is a fundamental machining process in material removal. Milling is a process of producing flat and complex shapes with the use of multi-tooth cutting tool, which is called a milling cutter and the cutting edges are called teeth. In milling process the important parameters we consider for analyze the efficiency of the operation are the surface roughness, cutting force and material removal rate. For an efficient milling operation, low surface roughness value, low force should be experienced on cutting tool and high material removal rate should be there. For this, we optimize these parameters by controlling some factors such as cutting speed, feed, depth of cut etc. In early days usually trial and error method is used by machine operators to fix this. But that is very time consuming process. So for this Taguchi's parameter design is used, because it offers a simple and systematic approach to optimize design for performance, quality and cost.

II. Literature Review

J.A. Ghani have optimized the machining parameters in end milling operation of hardened steel AISI H13 with Tin coated P10 carbide insert tool for high speed cutting conditions. The parameters he optimized in this study are resultant cutting force and surface finish. The control factors taken here are spindle speed, feed and radial depth of cut in three different levels. Taguchi design of experiment is used for the optimization purpose. A standard $L_{27}(3^{13})$ orthogonal array is used to accommodate these design factors simultaneously. The experiment is carried in Cincinnati Milacron Sabre 750 VMC in dry condition. The cutting forces are measured online during milling operation using Kistler dynamometer model 9275 A. surface roughness is measured by surface tester model Mpi Mahr Perthometer. The objective of experiment is to optimize the milling parameters to obtain to get low surface roughness value and low resultant cutting forces. The average S/N ratios for smaller the better parameters to be optimum is found. An alternative method for analysis of data for process optimization, Pareto ANOVA is also used. Both Taguchi and Pareto ANOVA methods draw similar conclusions. Surface roughness parameter significantly depends on cutting speed and cutting force depends on feed and depth of cut.

Julie Z Zhang optimized surface roughness in an end milling operation. Maintaining good surface quality involves additional cost and loss of time. So optimized control factors have to be found so can reduce the losses in time and cost. Taguchi method is used here for process parameter optimization. The control factors taken here are feed rate, splindle speed and depth of cut and operating chamber temperature and the usage of different tool inserts are the noise factors. Orthogonal array of L_9 was used. The purpose of this study is to efficiently determine the optimal milling parameters to achieve the smallest surface roughness value for aluminum parts under different conditions. Fadal VMC-40 is used for experimental operation. Federal Pocketsurf Stylus Profilometer is used to measure surface roughness. 1500WHoneywell Quick Heat Ceramic Heater is used to create different temperature conditions in shop floor and APKT 160408R coated carbide inserts are used for tooling. Including four combinations of noise factors (normal temperature with no tool wear, normal temperature with light tool wear, high temperature with no tool wear, and high temperature with light tool wear) 36 runs are done for the experiment. From the study it is seen that the effect of spindle speed and feed rate on surface were larger than depth of cut and the noise factor which is significant in surface finish is the tool wear.

Thakur Paramjit Mahesh in his study did the optimization of milling process parameters to minimize the surface roughness and maximize material removal rate simultaneously on Al 7075-T6 aluminium alloy. The control factors taken in consideration are feed, speed, depth of cut and nose radius of tool insert. L_{27} orthogonal array with all 4 factors at 3 levels are chosen. The signal to noise ratio is calculated by Taguchi design. For minimizing the surface roughness, lower the better in S/N ratio is taken and for maximizing the material removal rate, higher the better in S/N ratio is used. The most important factors affecting the responses are nose radius and depth of cut. A fuzzy logic unit is used to perform fuzzy reasoning of multiple performances and a confirmation run is done at last for the confirmation of results.

III. Methodology

Method presented in this study is an experimental design process called the Taguchi design method. Taguchi design, developed by Dr. Genichi Taguchi, is a set of methodologies by which the inherent variability of materials and manufacturing processes has been taken into account at the design stage. it seeks nominal design points that are insensitive to variations in production and user environments to improve the yield in manufacturing and the reliability in performance of a product. The Taguchi design only conducts the balanced (orthogonal) experimental combinations, which makes the Taguchi design even more effective than a fractional factorial design. By using the Taguchi techniques, industries are able to greatly reduce product development cycle time for both design and production, therefore reducing costs and increasing profit.

1. Larger the better (for example, agricultural yield);

$$S/N = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{{y_i}^2}\right)$$

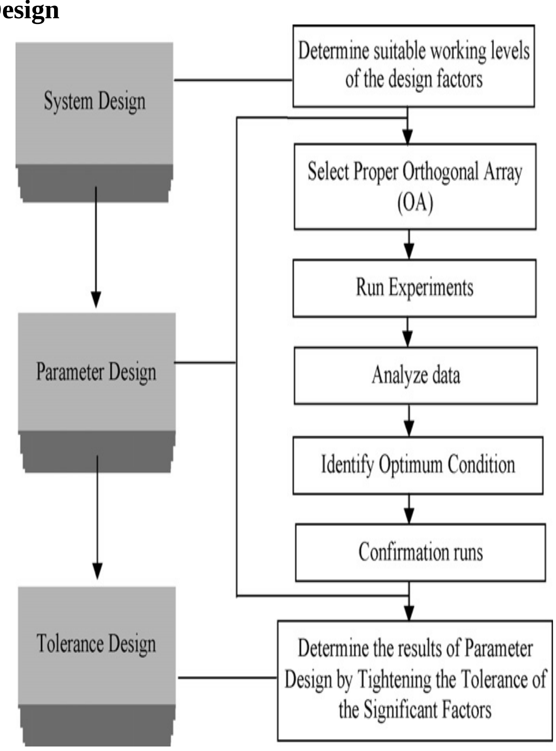
2. Smaller the better (for example, carbon dioxide emissions); and

$$S/N = -10\log_{10}\left(\frac{\sum {y_i}^2}{n}\right)$$

3. Nominal the better (for example, a mating part in an assembly).

$$S/N = 10\log_{10}\left(\frac{y^2}{s^2}\right)$$

3.1 Procedure Of Taguchi Design



IV. Experimental Set Up

The experiments are conducted on a TRM 5V versatile milling machine of HMT Kalamasseri Ltd. The objective of this experiment is to find the optimum level of control factors in milling operation to give less surface roughness and which control factor influence more in causing surface roughness.
Cutting tool inserts: APKT 160408R coated carbide inserts

4.1 Surface Roughness Measurement Device

The device used for measuring surface roughness is Federal Pocketsurf Stylus Profilometer (measures *R*a in _in.; stylus travel 0.1 in./2.54 mm).

Pocket-sized economically priced, completely portable instrument which performs traceable surface roughness measurements on a wide variety of surfaces; can be used confidently in production, on the shop floor and in the laboratory

Four switchable probe positions – axial (folded) or at 90°, 180° or 270°. Even difficult-to-reach surfaces such as inside and outside diameters are accessible. Integrated data output for SPC-processing units that is compatible with the most common data processing systems. Easy-to-read LCD readout presents the measured roughness value, in micro inches or micrometers, within half a second after the surface is traversed.

V. Analysis

5.1 Orthogonal Array And Experimental Factors

For conducting this optimization study, three control factors viz spindle speed in rpm, feed rate in mm/min and depth of cut in mm is selected in three levels. The spindle speeds and depth of cut were selected from within the range of parameters for finishing and semi-finishing milling of aluminum. The feed rates were slightly lower than normally used for milling aluminum workpieces, in consideration of safety concerns. An L_9 orthogonal array (3^3) is used to fit the data. Total 9 experiments are done for each setting of speed, feed and depth of cut and four trials are done for each setting.

Table 1. Levels Of Control Factors

Control Factors	Code	Level 1	Level 2	Level 3
Spindle speed , rpm	A	1500	2500	3500
Feed rate (mm/min)	B	508	762	1016
Depth of cut (mm)	C	1.52	2.03	2.54

Table 2. Completed Orthogonal Array

Run	Control factors			Trial runs				Surface roughness	S/N Ratio
	Speed	Feed	Depth of cut	N1	N2	N3	N4		
1	1	1	1	35.5	47	71.5	58.5	53.13	-34.77
2	1	2	2	59.5	58.5	51	69	59.50	-35.54
3	1	3	3	68.5	56.5	96.5	133	88.63	-39.41
4	2	1	2	26	23.5	82.5	53.6	46.40	-34.36
5	2	2	3	31	40	56	26	38.25	-32.02
6	2	3	1	45	41	58.5	49	48.38	-33.77
7	3	1	3	23.5	26.5	76.5	30.5	39.25	-33.03
8	3	2	1	24.5	22.5	51	56.5	38.63	-32.37
9	3	3	2	31.5	38	82	48	49.88	-34.57

Table 3. Roughness Response Table For Each Level Of Parameters

LEVEL	SPEED	FEED	DEPTH OF CUT
1	-36.57	-34.05	-33.64
2	-33.38	-33.31	-34.82
3	-33.32	-35.92	-34.82
Delta	3.25	2.61	1.19
Rank	1	2	3

VI. Results And Discussion

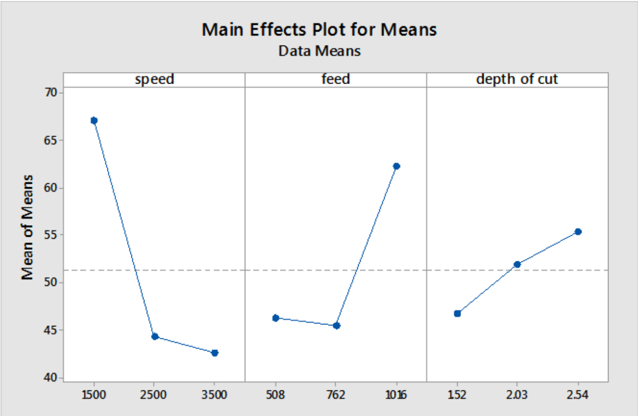


Figure 1. Main Effects Plot For Means

In this study, it is the-smaller-the-better case, which means the smallest surface roughness would be the ideal situation. Also the largest S/N ratio, reflecting the best response given the noise in the machine set-up system, would be the ideal situation. This is the criteria employed in this study to determine the optimal cutting condition

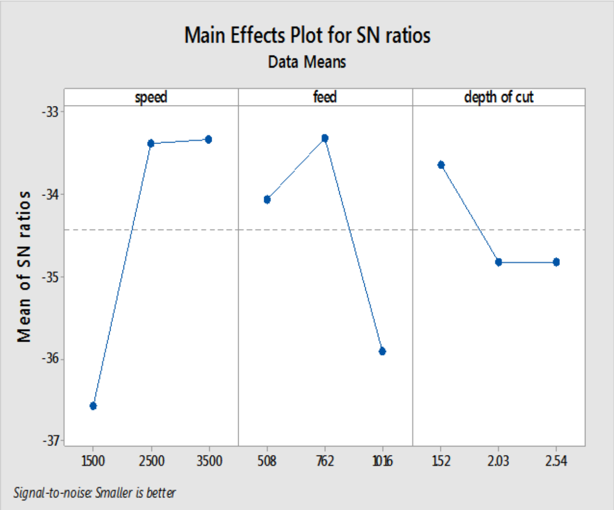


Figure 2. Main Effects Plot For SN Ratios

By following the criteria of smaller surface roughness and larger S/N ratio, the graphs was used to determine the optimal set of parameters from this experimental design.The control factor of spindle speed (A) at level 3 (3500 rpm) provided the best result. Similarly, the control factor of feed rate (B) at level 2 (30 ipm) provided the best result. Although depth of cut (C) was not a significant factor impacting surface roughness result, of the three set-up conditions, depth of cut at level 1 provided the lowest surface roughness and highest S/N ratio. Therefore depth of cut at level 1 (0.06 in./1.52 mm) was selected for the optimal cutting condition. The criteria of the lowest response and highest S/N ratio were followed and there are no conflicts in this study in determining the optimal spindle speed, feed rate, and depth of cut. Therefore, the optimized combination of levels for the three control factors from the analysis so far was A3-B2-C1

VII. Conclusion

In this study the optimal cutting condition for face milling was selected by varying cutting parameters such as cutting speed, feed rate and depth of cut and response parameter as surface roughness through the Taguchi Parametric design. The experimental results indicate that in this study the effects of spindle speed and feed rate on surface were larger than depth of cut for milling operation.

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