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SURFACE ROUGHNESS OPTIMIZATION IN END MILLING USING TAGUCHI METHOD AND ANOVA

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Abstract:
In this paper, the Taguchi method has been applied to optimize the machining performance in terms of surface roughness of the product, with aluminum 6061 work piece. Three different types of cutting tools were used of which two were HSS and one was Carbide for experiment on a CNC End Mill. Taguchi's L9 orthogonal array is employed for the experimentation. The factors considered for experimentation and analysis were spindle speed, feed rate, depth of cut and tool type. Signal-to-noise (S/N) ratio and analysis of variance (ANOVA) were employed to analyze the effect of these milling parameters. The analysis results revealed that the spindle speed was the dominant factor affecting surface roughness. Confirmation test results showed that the Taguchi method was very successful in the optimization of machining parameters for minimum surface roughness.

Keywords: Aluminium 6061, Tool Type, Taguchi's Method, CNC End Mill, ANOVA.

1.Introduction:

End milling is the vital milling operation and it is widely used in most of the manufacturing industries due to its competency of producing intricate geometric surfaces with acceptable accuracy. In end milling, surface finish and material removal rate are two significant parameters, which are in focus for manufacturing as well as in Research & Development, because these two factors extremely effect machining efficiency. The purpose of selecting CNC machine is parameter can be varied easily set as per requirement and during machining human interference are negligible, due to this the required accuracy and surface finish can be achieved in CNC machines. Aluminium alloys contains the typical alloying elements, such as copper, magnesium, manganese, silicon and zinc and in which Aluminium (Al) is the predominant metal. In the present investigation Aluminium 6061 has been taken as the workpiece material while HSS and Carbide as cutting tool. The reason for selecting Aluminum as a workpiece is its physical properties like lightweight, strength, recyclability, corrosion resistance, durability.

2. Literature Review

J. Pradeep Kumar, K. Thirumurugan [1] This paper describes a comprehensive study of end milling of titanium alloys. The study investigated the optimum parameters that could produce significant good surface roughness whereby reducing tooling cost. The control parameters were spindle speed, feed rate, depth of cut and type of end milling tool. Then, an orthogonal array of L27 (313) and analysis of variance (ANOVA) were carried out to identify the significant factors affecting the surface roughness. VISHAL PARASHAR [2] he has performed experiment on steel grade en19 material and coated carbide tool for optimization of surface roughness through taguchi's method. In his study, he found spindle speed is the main factor which affect the surface roughness. He investigated, increasing the spindle speed reducing the value of surface roughness and decreasing the speed of spindle increasing the value of surface roughness. S. Sakthivelu [3] In his research, he has done experiment on Aluminium Alloy 7075 T6 in CNC milling machine using High Speed Steel (HSS) cutting tool. Feed rate is most significant factor for surface roughness and depth of cut is most significant factor for material removal rate. Devesh Pratap Singh [4] Taguchi methodology to obtain optimum machining condition for surface roughness of aluminum in CNC turning operation. Feed Rate was most significantly affecting the Turning of Aluminum. The result showed that the feed rate contributed 54.65%, cutting speed contributed only 34.67% and depth of cut contributed was least with 10.47%. For surface roughness (Ra) optimum machining parameters are spindle speed 800 rpm, feed rate 40mm/min and depth of cut 0.5mm. Madhav MurthyȦ [5], In this study, the effect of various cutting parameters on the surface finish of Al6061 aluminium alloy was investigated using CNC LT-16 turner with carbide tipped tool. The factor feed is the most significant in influencing the surface roughness while the remaining three factors considered are not significant.

3.Taguchi's Method:

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "ORTHOGONALARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control parameters. Thus, the marriage of Design of Experiments with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

SMALLER-THE-BETTER:

$$SN_s = -10log_{10}(\sum y^2/\,n)$$

This is usually the chosen S/N ratio for all undesirable characteristics like "defects" etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is expected to be as small as possible value is expected to be as small as possible.

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4.Experimental Method:

The experiment of end milling is carried out on CNC End Mill machineV-350 equipped with maximum spindle speed of 8000 rpm, 3-axis, SEMENS controller. The work material used was Aluminium-6061 in the form of a 100mm×60mm×20mm block. The machining parameters which considerably affect the surface roughness are identified based on experience, discussion made with the expert, survey of literature, the parameters and their chosen levels are shown in table 1. The experiment was conducted using HSS and Carbide cutting tool. Two types of HSS tools were used, HSS1 was new tool whereas HSS2 was used tool. Carbide tool was new tool. Type 1 HSS tool, which is new tool is denoted by 1, type 2 HSS tool, which is old tool denoted by 2 and carbide tool is denoted by 3. The surface roughness of each specimen was tested on the surface roughness tester Mitutoyo 178-561-02A Surftest SJ-210 Surface Roughness Tester.

Table 1. Selected parameters and Levels

Factor	Level 1	Level 2	Level 3
Spindle Speed (rpm)	2500	3800	5000
Feed(m/min)	1000	1300	2500
Depth of cut(mm)	0.50	0.96	1.16
Type of tool	1	2	3

Fig.1Milling Operation on CNC

Fig. 2 HSS-1 Tool

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Fig. 3 HSS-2 Tool

Fig. 4 Carbide Tool

Each experiment was conducted three times to get authentic value and then mean value were calculated. These values are shown in table no.2. According to the Taguchi method, the S/N ratio is the ratio of signal-to-noise where signal represents the desirable value (i.e. the mean for the output characteristic), and noise represents the undesirable value (i.e. the square deviation for the output characteristic). Therefore, the S/N ratio is the ratio of mean to square deviation. Its unit is dB. The S/N ratio for each experimental run is calculated by using the following equation (1).

S/N = -10log [MSD].. (1)

MSD stands for mean square deviation, which is also a measure of the dispersion of the data.

Table 2. Response and S/N Ratio for Surface Roughness

Spindle Speed (rpm)	Feed Rate (m/min)	Depth of Cut (mm)	Tool Type	Mean Roughness(µm)	S/N Ratio
2500	1000	0.50	HSS1	51.50	-34.2361
2500	1300	0.96	HSS2	53.13	-34.5068
2500	2500	1.16	CARBIDE	49.88	-33.9585
3800	1000	0.96	CARBIDE	48.38	-33.6933
3800	1300	1.16	HSS1	80.63	-38.1299
3800	2500	0.50	HSS2	38.63	-31.7385
5000	1000	1.16	HSS2	39.25	-31.8768
5000	1300	0.50	CARBIDE	41.40	-32.3400
5000	2500	0.96	HSS1	38.25	-31.6526

Table 3. Response Table for Signal to Noise Ratio (Smaller is better)

Level	Spindle Speed	Feed Rate	Depth of Cut	Tool Type
1	-34.23	-33.27	-32.77	-34.67
2	-34.52	-34.99	-33.28	-32.71
3	-31.96	-32.45	-34.66	-33.33
Delta	2.56	2.54	1.88	1.97
Rank	1	2	4	3

ANOVA Results:

The main factors that significantly effecting the surface roughness is spindle speed. ANOVA was done to study the effect of the end milling process variables. The results obtained from ANOVA are shown in table 4.

Table 4. Analysis of Variance for Surface Roughness

Source	DF	Adj SS	Adj MS	F	P	Contribution (%)
Spindle Speed	2	424	212	1.3	0.339	30.26842%
Feed	2	421.5	210.8	1.29	0.342	30.08995%
Depth of Cut	2	269.9	135	0.72	0.526	19.26756%
Type of Tool	2	285.4	142.7	0.77	0.505	20.37407
Total	8	1400.8	700.5	4.08	1.712	100

It was found from figure 1, that the spindle speed with 5000 rpm, 2500 m/min of the feed rate, 0.50 mm depth of cut and HSS 2 is the type of tool by using these parameters can achieve the minimum value of surface roughness. The optimal factor levels obtain from main effects plot of S/N Ratio for surface roughness is shown in table 5.

Table 5. Optimal Factor Levels for Surface Roughness

Sr. No.	Factor	Optimum Level	Optimum Value
1	Spindle Speed(rpm)	3	5000
2	Feed(m/min)	3	2500
3	Depth of Cut(mm)	1	0.50
4	Type of Tool	2	HSS 2

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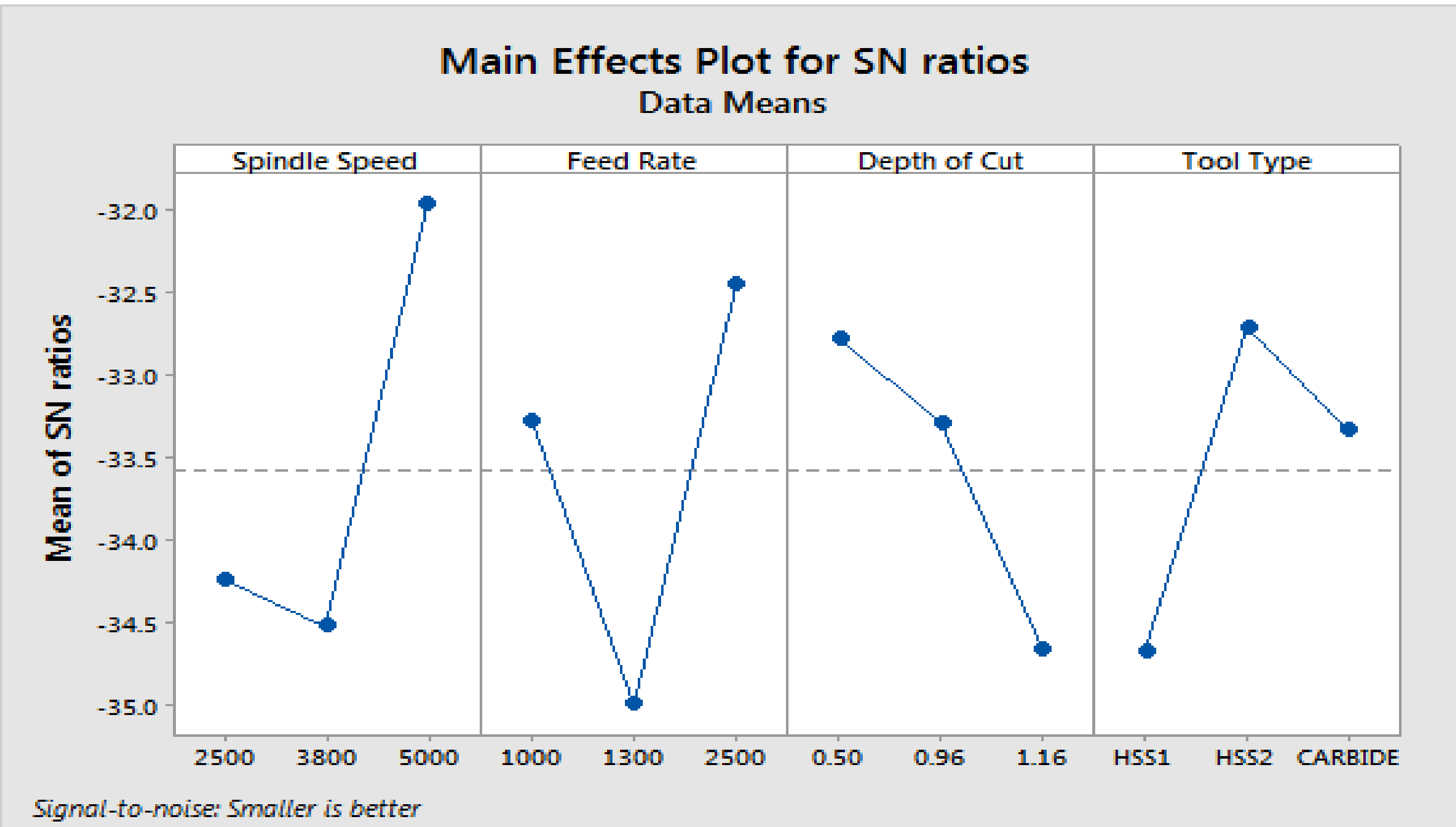

Fig. No. 1 Main effects plot for SN ratios

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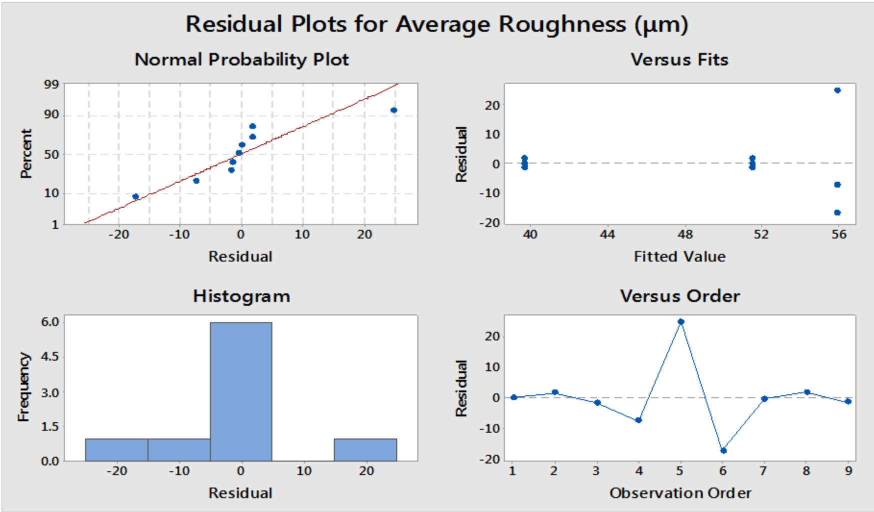

Fig. No. 2 Residual plots for average roughness

Figure 2 depicts normal plot of residuals. This plot is used to test the normal distribution of errors. If the underlying error distribution is normal, this plot will resemble a straight line. This distribution shown in figure 2 presents that the error normality assumption is valid. The same figure shows plotting of the residuals in time order of data collection. This method is helpful in checking independence assumption on the residuals. It is desired that the residual plot should contain no obvious patterns. Figure presents that independence assumption on the residuals was fulfilled for this experiment. This figure also shows plot of residual versus fitted values. The structure less distribution of dots above and below the abscissa (fitted values) shows that the errors are independently distributed and the variance is constant. Therefore, it can be concluded that the assumption of constant variance of residuals was satisfied. Now those assumptions are proved not to be violated through this experimentation it can be relying on ANOVA results.

Conclusion:

1. Taguchi method of experimental design has been applied for optimizing multi– response process parameters for CNC End Milling Al 7075 T6 Alloy with L9 orthogonal array.
2. From Table 3 and Table 4, Spindle Speed is the most influencing parameter for minimum surface finish which is followed by feed, type of tool and depth of cut.
3.Optimal parameters for minimum surface roughness are Spindle speed = 5000 rpm, Feed rate = 2500m/min, Type of tool is HSS 2 and Depth of cut = 0.50 mm.

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