Effect of Machining Parameters on Surface Roughness of Al-7075 Alloy in End Milling

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Abstract - ***In the present work focus is given on the influence of spindle speed, feed rate and depth of cut on the surface roughness of Al-7075 alloy during end milling. The work piece used was of 6mm thickness, end mill tool of 10mm diameter, 4 flutes was used to perform experiments. Eight experimental runs based on an L8 orthogonal array of Taguchi design method are employed to investigate the machining characteristics of Al-7075 alloy. In this research S/N ratio analysis for smaller the better characteristics is used to obtain lower surface roughness. From the results of ANOVA, it is concluded that spindle speed and feed rate are the most significant factors affecting the response, their contribution in an order of 34.78% and 46.36% respectively.***

Key Words: *End Milling; Taguchi Design Method; S/N ratio; ANOVA.*

Nomenclature

Ra	Surface Roughness (μm)
N	Spindle speed
F	Feed Rate
D	Depth of Cut

Greek Symbols

η	Signal to noise ratio

1. INTRODUCTION

Aluminium alloys are extensively used as a main engineering material in various industries such as automotive industries, the mould and die components manufacture and the industry in which weight is the most important factor. These materials help machining and possess superior machinability index. With the highly automated and computer integrated manufacturing environment, milling process is one of the most vital and common metal cutting operations used for machining parts because of its ability to remove materials faster with a reasonably good surface quality.Milling is one of the most commonly used machining processes in aluminium alloys shaping.

Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties like corrosion resistance, creep life, wear resistance, ductility, tensile, fatigue strength, etc. for machined parts and cannot be neglected in design. Sometimes, various catastrophic failures causing high costs have been attributed to the surface finish of the components in question.

J.A.Ghani et al. [1] applied the Taguchi optimization methodology to optimize cutting parameters in end milling when machining hardened steel AISI H13 with TiN coated P10 carbide insert tool under semi-finishing and finishing conditions of high speed cutting. The milling parameters evaluated are cutting speed, feed rate and depth of cut. An orthogonal array, signal-to-noise (S/N) ratio and Pareto analysis of variance (ANOVA) are employed to analyze the effect of these milling parameters. The analysis of the result shows that the optimal combination for low resultant cutting force and good surface finish are high cutting speed, low feed rate and low depth of cut. Other significant effects such as the interaction among milling parameters are also investigated.

K.Kadirgama et al. [2] presented optimization of the surface roughness using RSM when milling Mould Aluminium alloys (AA6061-T6) with carbide coated inserts. The variables considered are cutting speed, federate, axial depth and radial depth. The first order model and RBFN indicates that the feed rate is the most significant factors affecting surface roughness. RBFN predict surface roughness more accurately compared to RSM.

John D. Kechagias et al. [3] investigated the effects of the process parameters during end milling of Al alloy 5083 on the surface texture parameters (arithmetical mean roughness, Ra; maximum peak, Ry; and ten-point mean roughness, Rz). The proposed approach combines the Taguchi design of experiments and statistical analysis of the results. Two-flute end cutters were used. The process parameters tested are: A, core diameter (%); B, flute angle (o); C, rake angle (o); D, peripheral 1st relief angle (o); E, peripheral 2nd relief angle (o); F, depth of cut (mm); G, cutting speed (rpm); and H, tool feed (mm/flute). Finally, optimal values of the process parameters were derived inside the experimental region, and the optimum end cutter was manufactured and tested using a validation experiment.

Surasit Rawangwong et al. [4] investigated the effect of main factors of the surface roughness in aluminium 7075-T6 face milling. The study was conducted by using CNC milling machine with fine type carbide tool with twin cutting edge. The controlled factors were the speed, feed rate and the depth of cut. The result with factorial design showed that the feed ratio and the speed affect surface roughness while the depth did not affect the surface roughness.

Lohithaksha M Maiyar et al. [5] investigated the end milling operation for Inconel 718 super alloy using grey relational analysis. Nine experimental runs based on an L9 orthogonal array were performed. Cutting speed, feed rate and depth of cut are optimized with considerations of multiple performance characteristics namely surface roughness and material removal rate. A grey relational grade obtained is used to solve the end milling process with the multiple performance characteristics. Additionally, the analysis of variance (ANOVA) is also applied to identify the most significant factor. Finally, confirmation tests were performed to make a comparison between the experimental results and the model developed.

As a result, there have been many great research developments in modelling surface roughness optimization of the controlling parameters to obtain desired level. Parameters that affect surface roughness include machining parameters, cutting tool properties and workpiece properties etc. Nevertheless, such studies are far from completion since it is very difficult to consider all the parameters that control the surface roughness for a particular manufacturing process. In the present study, a Taguchi design method and surface roughness in end milling of Al-7075 alloy material. The factors considered in the experiment were the spindle speed, feed rate and depth of cut. Taguchi L8 orthogonal array was used to layout of experimental plan as per factors and levels considered.

2. EXPERIMENTAL SET UP

The workpiece used for experiments is of Al-7075 alloy. The detailed information on composition and properties of the alloy material is shown in the Table 1 and 2. Workpiece plate of 6mm thickness is used. In this study the experiments were carried out on Siemens 828D CNC trainer 3 axes MTAB make vertical milling machine. Slots of 10mm width were performed on the Al-7075 alloy by Tungsten carbide 10mm, four flute end milling tool produced by Vedant tools as shown in fig.1. Then end milling operations were performed by varying spindle speed, feed rate and depth of cut. The machined surface was measured at three different positions using a SJ-210 surftest (Make-Mitutoyo) measuring instrument with ISO 1997 roughness standards, 2.5mm X 5 cut off length and the average surface roughness Ra also known as arithmetic mean roughness value is measured in microns.

Fig.1.Experimental set up for end milling


Fig.2. Set up for surface roughness measurement

Table 1. Composition of Al-7075

Element	Weight %	Element	Weight %
Zn	5.1-6.1	Fe	Max 0.5
Ti	Max 0.2	Cu	1.2-2
Si	Max 0.4	Cr	0.18-0.28
Mn	Max 0.3	Al	87.1-91.4
Mg	2.1-2.9		

Table 2 Mechanical Properties of Al-7075

Mechanical Property	**Value**
Modulus of elasticity	71.7 (Gpa)
Density	2810 (kg/m3)
Hardness	150 (BHN)
Ultimate Tensile Strength	572 (Mpa)

3. EXPERIMENTATION AS PER TAGUCHI DESIGN METHOD

In research and development works different methods are used for designing plan of experimentation to improve productivity and to lower the cost. In this experimentation was carried out by based on plan designed by Taguchi technique and data related to each experiment is then acquired. An orthogonal array, signal to noise (S/N) ratio, analysis of variance (ANOVA) are used to find the effect of different cutting parameters on the response. In this work there are three factors and each at two levels so depending upon the degrees of freedom of each parameter proper orthogonal array is selected i.e. L8.
Table 3 shows different parameters and their levels. Table 4 shows the experimentation plan and response obtained for each experiment.

Table 3: Machining parameters and their levels

Symbol	Parameters	Units	Level 1	Level2
N	spindle speed	Rpm	2000	2500
F	feed rate	mm/min	240	320
D	depth of cut	Mm	2	2.5

Table 4: Experimental plan and response

Exp No.	Machining Parameters			Response
	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of cut (mm)	Average Surface Roughness (µm)
1	1	1	1	0.5893
2	1	1	2	0.5613
3	1	2	1	0.6183
4	1	2	2	0.6423
5	2	1	1	0.402
6	2	1	2	0.4347
7	2	2	1	0.5557
8	2	2	2	0.6253

In Taguchi technique, S/N ratio analysis is there by which we can find the desirable (signal) and undesirable (noise) values for response characteristics. The S/N ratio is defined as

$$\eta = -10 ln_{10} \frac{1}{n}\sum_{i=1}^{n} y_i^2$$

Where, y_i is the value of average surface roughness for i-th test.
In this research we require the lower surface roughness so lower-the-better quality characteristic is selected to obtain optimum surface roughness.

4. RESULT AND DISCUSSION

4.1 Signal to Noise ratio:

Table 5: Signal to Noise Ratios (For Smaller is better)

Level	Spindle Speed A(rpm)	Feed Rate(mm/min)	Depth of Cut(mm)
1	4.408	6.19	5.447
2	6.083	4.301	5.044
Delta	1.676	1.89	0.403
Rank	2	1	3

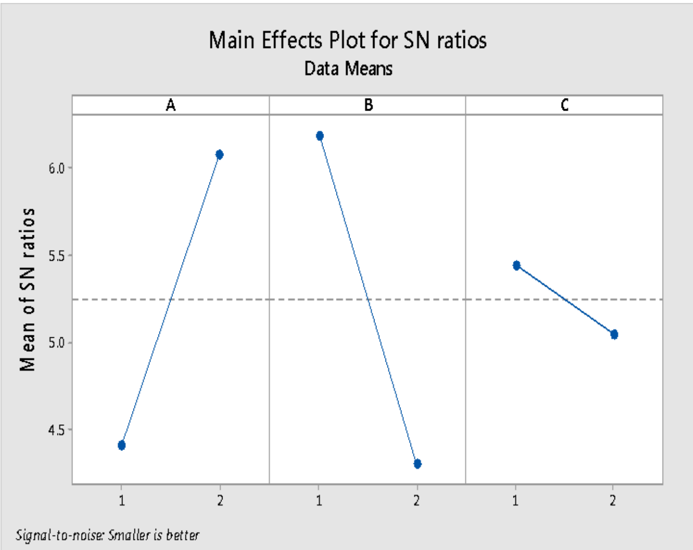

Fig.3 Main effect plot for S/N ratios

It is seen from the Table 5 that delta for the feed rate is max so the effect of feed rate is maximum on the surface roughness , spindle speed has moderate effect and depth of cut has minimum effect on the surface roughness.
It is seen from Fig.4.1 that S/N ratios are higher for the level 2 for spindle speed, level 1 for feed rate, level 1 for

depth of cut so the optimal parameter combination to get minimum surface roughness is to select these levels i.e. A2B1C1. Fig.4 shows interaction between parameters is significant.

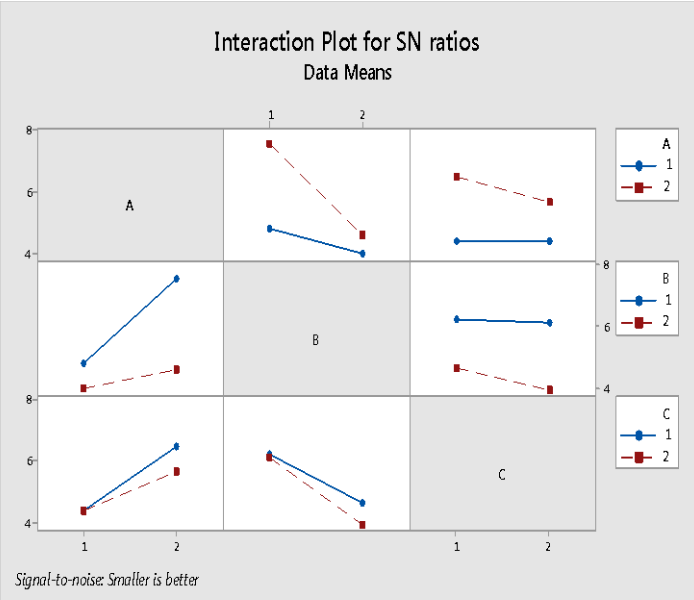

Fig.4 Interaction plot for surface roughness

Confirmation Test:

Analysis of variance is used to find which machining parameters significantly affect the response characteristic.
Table 6: ANOVA for Surface Roughness

Source	DF	% Contribution	SS	MS	F
Spindle Speed	1	34.78	0.019355	0.019355	8.33
Feed Rate	1	46.36	0.025799	0.025799	11.11
Depth of Cut	1	2.17	0.001208	0.001208	0.52
Error	4	16.69	0.009291	0.002323	
Total	7	100	0.005565		

From F table at 95% confidence level, at F 0.05,1,4 =7.71

From Table.6 it is observed that Fexp ≥ Ftable for spindle speed and feed rate so these two factors are significant and for depth of cut it is less so it is insignificant. Also feed rate has more contribution 46.36%, then spindle speed has moderate contribution 34.78% and depth of cut has less contribution for the surface roughness of Al-7075 alloy during end milling with 10mm, 4 flute tungsten carbide tool.

5. CONCLUSION

In this research machining characteristic of Al-7075 alloy i.e. surface roughness is studied for end milling with four flute, 10mm diameter tungsten carbide tool. It is seen From S/N ratio graphs optimal setting of machining parameters for low surface roughness obtained is 2500 rpm, 240 mm/min and 2.0 mm for spindle speed, feed rate and depth of cut respectively. It is observed from S/N ratio table that feed rate has more effect, spindle speed has moderate effect and depth of cut has less effect on surface roughness. Also confirmation test by using ANOVA shown that feed rate has more contribution 46.36%, spindle speed has moderate contribution 34.78% and depth of cut has less contribution.

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