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Research Article

Optimization of Machinability Parameters of Al6061 using Taguchi Technique

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Abstract

In the present day and age, manufacturing industries strive to reduce costs while at the same time increase quality of a component. This can be done effectively only after detailed studies have been carried out in the various areas of manufacturing sciences, i.e.: forging, material removal using machine tools, casting, forming, etc. Material removal using machine tools is a relatively expensive process, which is labor intensive and depends on the skill of the laborer. In recent times the focus is shifting to CNC machines due to its inherent advantages. Hence studying the parameters affecting the surface finish of a component in a CNC machine is of utmost importance. Various parameters which affect the surface roughness will be considered with enough variations in the parameters to arrive at a conclusive result. Of course, the parameters having more influence on the surface roughness will be given more importance. In this study, the effect of various cutting parameters on the surface finish of Al6061 aluminium alloy was investigated. Based on Taguchi method of design of experiments L16 orthogonal array was selected for conducting turning experiments on Al6061 T6 using CNC LT-16 turner with carbide tipped tool and the cutting parameters selected were feed, spindle speed, depth of cut and tool nose radius. The L16 array used 4 factors at 2 levels each and the experiments were conducted in temperature controlled environment. The results obtained were analyzed using ANOVA and the regression equation for predicting the surface roughness was developed.

Keywords: *Cutting parameters aluminium alloy ANOVA Surface roughness*

1. Introduction

Surface roughness is one of the prime factors in assessing the quality of a component and has received serious attention over the years. Surface roughness imposes one of the most critical constraints for selection of machines and cutting parameters in process planning. The efficiency of any machining operation depends on the overall rigidity of the system consisting of the machine tool, the cutting tool and the work piece. The machine on which the material is to be machined should be rigid and should have sufficient strength to withstand the induced cutting forces and to minimize deflections. If the machine is not sufficiently rigid, then the accuracy and surface finish will be affected. To limit the induced cutting forces speed, feed and depth of cut have to be reduced. Thus, the machinability of the material is affected by the machine variables.

In the recent past, many studies have been made on the effect of factors such as feed, speed and depth of cut in the turning process. Chao-Lieh Yang in his work on optimizing the Glass Fiber Cutting Process using the Taguchi Methods and Grey Relational Analysis found that the most significant cutting parameters are the cutting speed, which accounted for 47.21% of the total effect, followed by the cutting volume and the cutting load which accounted for 14.62%and 12.20% respectively of the total effect. In their work on optimizing the rapid prototyping process by integrating the Taguchi method with the Gray relational analysis, Che Chung Wang et al [2] found that the maximal Tensile Strength of the shaping test specimen is enhanced up to 90.48 % and the Dimensional Accuracy is enhanced up to 99.36 %. In his work on parameter design study in turning operation using the Taguchi method Daniel Kirby used spindle speed, feed rate and depth of cut as controlled factors and concluded that Feed rate had the highest effect on surface roughness, spindle speed had a moderate effect, and depth of cut had an insignificant effect. Harish Kumar et al in their work on optimization of cutting parameters in CNC Turning used cutting speed, feed rate and depth of cut as the factors and found that the most affecting parameter is speed having the impact of 59.9%. Kromanis et al in their work on prediction of surface roughness in end milling used Taguchi technique to develop the regression equation with cutting speed, feed and depth of cut and concluded that technological parameter range also plays a very important role on the surface roughness achieved. Mathew A.

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Kuttolamadom et al in their study on the effect of Machining Feed on Surface Roughness in Cutting 6061Aluminum proposed to increase the feed up until a cut-off surface roughness limit is reached and then increase the surface speed within the roughness range, to maximize productivity. Venkata Ramana et al in their work on the performance evaluation and selection of optimal parameters in turning of Ti-6Al-4V alloy under different cooling conditions concluded that that feed rate is dominant parameter under dry, servo cut oil with water and synthetic oil conditions in optimizing the surface roughness. Yang et al in their work on design optimization of cutting parameters for turning operations based on the Taguchi method found that there was improvement in tool life and surface roughness by 250% after applying the Taguchi technique in comparison to the initial parameters.
From the above studies, it is evident that there has been no attempt of considering tool nose radius as one of the controlling factors. In the present work, tool nose radius has been considered as one of the factors in addition to cutting speed, feed and depth of cut that influence the surface roughness.

2. Design of Experiments

The major steps involved in DOE experimentation process are

Step1: Statement of the problem: This step addresses the purpose of carrying out experiments.
Step2: The objective function: This step defines the objective of data analysis after the experiments are conducted.
Step3: Selection of quality characteristic: In this step, the quality characteristic which is to be measured experimentally is decided.
Step4: Selection of factors: In this step, the factors which influence the output are selected.
Step5: Identify Control and noise factors: Control factors are the factors which can be controlled and noise factors are those which cannot be controlled. In this step, these two factors are decided.
Step6: Select levels for the factors and corresponding Orthogonal Arrays:
In this step, the levels at which the controlled factors have to be varied is decided as the experimentation depends on these levels. This step is the critical planning phase of the process which involves carrying out of the experimentation process to obtain appropriate result. In this work, L16 orthogonal array is selected taking main effects into consideration.
Step7: Conduct trials described by orthogonal arrays: This step involves the experimental procedure which helps in performing of experiment using orthogonal.
Step8: Analyze results of the experimental trials: This step involves the analysis of test results obtained from experiments conducted.

3. Experiments

3a. Turning

Figure 1: ACE FANUC LT-16

Figure 1 is an industrial lathe with sufficient uptime to have its very own unique characteristics. This lathe was used to conduct the experimental process. The key specifications of the ACE model LT-16 industrial lathe with FANUC controller are given in Table 1.

Table 1: ACE FANUC LT-16 Specifications

Maximum turning diameter	270mm
Maximum turning length	400mm
Chuck Size	165mm
Spindle Power (30 Min)	7.5kW
Rapid Rate X/Z Axis	20m/min
Lubrication	Automatic, Centralised
Turret	High speed Bi-Directional
Number of Tool Stations	8 Nos
Tool Shank size	20 x 20 mm

The output parameter for the turning experiments was surface roughness and the input factors were feed, spindle speed, depth of cut and tool nose radius. These were varied at two levels each as below

1. Feed :10 mm/min and 70 mm/min
2. Spindle speed :500rpm and 1500 rpm
3. Depth of cut :0.2 mm and 0.8mm
4. Tool nose radius : 0.2 mm and 0.8mm

3b. Measurement of Surface Roughness

A Profilometer is a device used to measure the roughness of a given surface profile. Figure 2 shows Mitutoyo SJ-201P Profilometer and the specifications of the Profilometer are given in Table 2.

Figure 2: Mitutoyo SJ-201P Profilometer

Table 2: Mitutoyo SJ-201P Profilometer Specifications

Measuring Range	12.5mm
Measuring Speed	0.25, 0.5 mm/s
Traversing Direction	Backward
Detector Range	350µm (-200µm to +150µm)
Detecting Method	Skid Measurement
Measuring Force	4mN or 0.75Mn
Stylus tip	Diamond, 90º/5µmR
Skid radius of Curvature	40mm
Skid force	Less than 400mN
Detecting Method	Differential Inductance
Power Supply	Via AC Charger or Inbuilt Battery
Battery Life	Max. 600 measurements (w/o Printing)
Recharge time	15hrs
Data Output	RS-232C Interface/SPC output
Mass of Control Unit	0.3kg
Mass of Drive Unit	0.2kg
Applicable Standards	JIS82, JIS01, DIN, ISO, ANSI
Evaluation Parameters	Ra, Ry, Rz, Rq, S, Sm, Pc, R3z, mr©, Rt, Rp, Rk, Rpk, Rvk, Mr1, Mr2, A1, A2, Vo
Cut-Off Length	0.25, 0.8. 2.5 mm
Number of Sampling Length	*1, *3, *5
Arbitrary Length	0.3 to 12.5 mm

4. Results and Discussions

4a. Surface roughness

Table 3 gives the surface roughness values for the 16 experiments conducted.

4b. Main Effects Plot

Figure 3 shows the main effects plot obtained using Minitab version 15. The objective function selected is smaller the better. With the signal to noise ratio, the topmost points in each factor gives the optimum condition. The optimum conditions where the roughness is minimum are 0.2mm nose radius, 10 mm/min feed, 1500rpm speed and 0.2mm depth of cut.

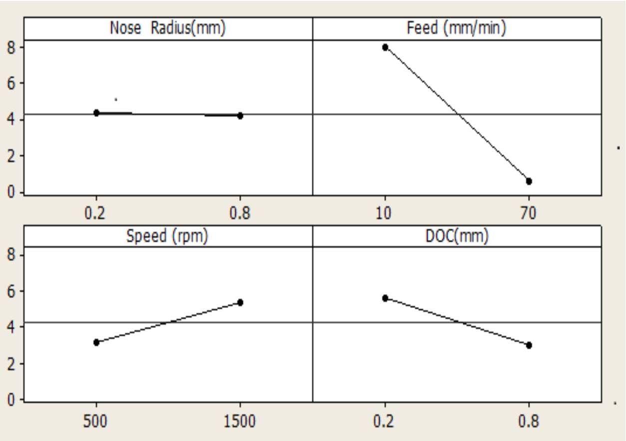

Figure 3: The Main Effects Plots

4c. ANOVA

Table 3: L16: Results of Surface roughness measurements after turning

Trial No	Nose Radius(mm)	Feed (mm/min)	Speed (rpm)	DOC (mm)	Ra
1	0.2	10	500	0.2	0.36
2	0.2	10	500	0.8	0.31
3	0.2	10	1500	0.2	0.25
4	0.2	10	1500	0.8	0.31
5	0.2	70	500	0.2	1.23
6	0.2	70	500	0.8	2.66
7	0.2	70	1500	0.2	0.69
8	0.2	70	1500	0.8	0.85
9	0.8	10	500	0.2	0.25
10	0.8	10	500	0.8	0.32
11	0.8	10	1500	0.2	1.02
12	0.8	10	1500	0.8	0.84
13	0.8	70	500	0.2	0.76
14	0.8	70	500	0.8	2.30
15	0.8	70	1500	0.2	0.36
16	0.8	70	1500	0.8	0.45

Table 4: F and P static

Source	F	P
Nose Radius(mm)	0.02	0.894
Feed (mm/min)	4.93	0.048
Speed (rpm)	1.80	0.206
DOC(mm)	1.50	0.247

Table 3 shows the F and P static of the ANOVA analysis of the experimental results. The factor feed has the maximum F static and has P static less than 0.05. Hence feed is the most significant factor which affects the surface roughness. The R square value is 42.84% indicating a large variation in surface roughness.

4d. Regression

The regression equation developed for predicting surface roughness using Minitab version 15 is shown in equation 1. The R square value is 42.8% indicting large variation in surface roughness.

Ra = 0.484 - 0.072 Nose Radius (mm) + 0.0118 Feed (mm/min)- 0.000427 Speed (rpm) + 0.648 DOC(mm) - (1)

Conclusion

From the above discussion, it can be concluded that
The factor feed is the most significant in influencing the surface roughness while the remaining three factors considered are not significant.

The R square value for the regression equation developed to predict surface roughness is 42.8% indicting requirement of conducting further tests with more levels of feed.

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