Effect of turning parameters on Al6351 T6 by using Design of Experiments

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Abstract. Aluminium is a well known lightest engineering metals. It is the most productive element on the earth crust. It can be extracted from bauxite, kaolinite or nepheline. It can be used in making aeroplane bodies, automobile parts *etc*. It is mostly used in multiple applications in order to reduce the weight of the component and it has fancy corrosion resistance. In the present study Al 6351 T6 is selected and a plain turning operation is performed on it with the help of design of experiments. The surface roughness of the samples are tested by varying the cutting parameters such as speed, feed, and depth of cut. A mathematical model is developed and the parameter which affects the surface roughness is determined.
Keywords. Cutting parameters, Design of experiments, Surface Roughness, plain turning.

1. Introduction

Engineering components require dimensional , shape accuracy and good surface finish. Machining to high accuracy and finish essentially enables a product to fulfill its functional requirements, improve performance and extend its Service. The fundamental principle of machining is a metal rod of regular shape, size and surface is converted into a finished size of desired dimension and surface by machining by important relative motions of the tool-work pair. Machining is significant because it gives good dimensional accuracy and good surface finish to a product. Surface quality of the product improves fatigue strength, corrosion resistance, hardness, toughness and creep life. Al 6xxx series is commonly heat treatable alloy. Al 6351 T6 is an Al-Mg-Si alloy solution heat treated followed by artificial ageing. Chemical composition of this alloy is Mg (0.4-1.2%) and Si (0.6-1.3%). Al 6351 T6 is mainly accessible in the form of rods, flats, tubes. It is mainly used in structural and general engineering applications such as rail and road transportation, vehicles, bridges, cranes, roof trusses, rivets *etc.* ultimate tensile strength of Al 6351 T6 is 31.5 MPa. The Aim of the present study was properly to develop the surface roughness prediction model and optimization of cutting parameters with assist of statistical method by using full factorial design of experiments.

2. Results

The experiment was conducted using one work piece material namely Al 6351 T6. The cutting tool used standard carbide tool TN 2000. This tool has required bulk toughness and has multilayer *MTCVD* coating that provides the wear resistance and crater resistance. It is an optimum grade and used as the first ace in medium machining. It provides required chip impact resistance to give longer tool life.

The tests were carried for a length of 100mm in a TL 160L CNC lathe. The dimension 2.2m*1.6m*1.8m (Length* width*Height). It has hydraulically operated tail stock and centralized lubrication. The maximum feed that this lathe can adapt is 10000 mm/min. The length of tailstock is 70mm and chuck size is 165mm.

The cutting parameters are shown in table 1. Two levels of cutting speed, two levels of feed, two levels of depth of cut were used as shown in table 1.

Table 1. Cutting parameters and their limits.

S.no	Parameters	Upper limit	Lower limit
1	Speed(rpm)	2500	1500
2	Feed(mm/rev)	0.18	0.12
3	Depth of cut (mm)	1.5	1.0

A full factorial design has to be developed by using Minitab 17 software as shown in table 2

Table 2. Full factorial design table

Std Order	Run Order	Speed	Feed	Depth of Cut
7	1	1500	0.18	1.5
1	2	1500	0.12	1.0
2	3	2500	0.12	1.0
8	4	2500	0.18	1.5
6	5	2500	0.12	1.5
3	6	1500	0.18	1.0
4	7	2500	0.18	1.0
5	8	1500	0.12	1.5

Totally 8 experiments were conducted. The surface roughness of8 components are determined for different speed, feed, depth of cut and are shown in table 3. The surface roughness was measured by using the masterpiece equipment called SURFCOM 130A. The inspection approach is direct measurement. The components are inspected at a temperature range between 19.5°c to 20.05°c and at a RH range between 40 to 60%. The responses are shown in table 3. The table 3 gives us distinct cutting parameters for each experiment and the results are shown in last column of the table. The different cutting parameters used are cutting speed in rpm; feed in mm/rev; depth of cut in mm and the resultant surface roughness Rz will be in microns. No lubricant or cutting fluid is used while machining, i.e. a dry plane turning process was used.

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Table3. Measured Surface roughness table

Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)	Surface Roughness(microns)
1500	0.18	1.5	12.250
1500	0.12	1.0	10.685
2500	0.12	1.0	12.856
2500	0.18	1.5	12.035
2500	0.12	1.5	10.755
1500	0.18	1.0	12.910
2500	0.18	1.0	11.750
1500	0.12	1.5	8.785

The experimental values are fed in to the Minitab 17 software. The design of experiment is an significant tool for modelling and analysis of the affect of cutting parameters on the response. In the present study cutting speed, feed, depth of cut are considered as factors. Regression analysis is used to verify the model relationship between a response variable and one or more predictors. By using design of experiments and regression analysis some of the graphs were plotted like main effects plot for surface roughness, interaction plot for surface roughness, Pareto chart of the effects, normal plot of the effects. The main effects plot for surface roughness is shown in figure 2. Plotted by taking parameter values on x-axis and response value on y-axis. The dotted line is the main effects plot for surface roughness that indicates the mean response value. Similarly interaction plot for surface roughness, Pareto chart, normal effects plot are shown in fig 3,4,5 respectively.

Interaction graphs are plotted for each combination of levels. Figure 3 shows the interaction between important parameters. The effects of different parameters can be analyzed by Pareto and normal plot graphs. Pareto chart gives the magnitude of the effect and a reference line is drawn on the graph. The parameter which is closer to this dotted line is to be considered for getting better surface finish for Al 6351 T6.

Normal plot graphs are used to identify the effects of factor. The normal plot is constructed based on central limit theorem. The points which are far away from straight line will have a significant effect on surface roughness. In this case the feed factor is to be considered as important.

A mathematical model has been developed by considering the intermediate values for speed, feed, depth of cut as 2000 rpm, 0.15mm/rev, 1.25mm respectively. Surface roughness is a function of speed, feed, and depth of cut. It can be mathematically represented as

- Surface roughness = f(A, B, D) (1)

And the equation can be written as[14]

- Surface roughness = C+C1*A+C2*B+C3*D (2)

Where C = average response value
C1,C2,C3 = coefficients that depends on main effects and interaction effects
By using Minitab 17 software significant coefficients were found and final surface roughness equation was developed as shown below

- Surface roughness = 9.19+0.000692*speed+24.4*feed- 2.19*depth of cut (3)

Speed, feed, depth of cut values are substituted in the above equation and the surface roughness obtained is 11.4965 microns. The actual value of surface roughness is 9.255 microns. The experimental value and the actual values are compared and error is noted in the table 4.

Table 4. Comparison of actual and experimental values

Speed(rpm)	2000
Feed(mm/rev)	0.15
Depth of cut(mm)	1.25
Experiment value	11.4965
Actual value	9.255
Percentage Error	19.49%

Figure 1. Machined components of Al6351T6 alloy

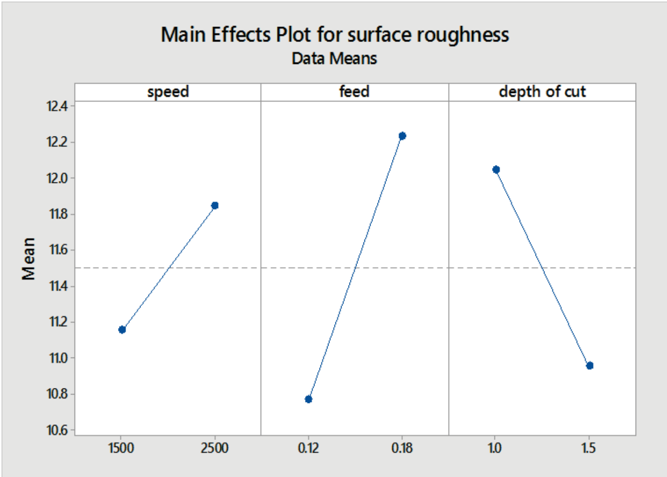

Figure 2. Main effects plot for surface roughness

Figure 3. Interaction plot for surface roughness

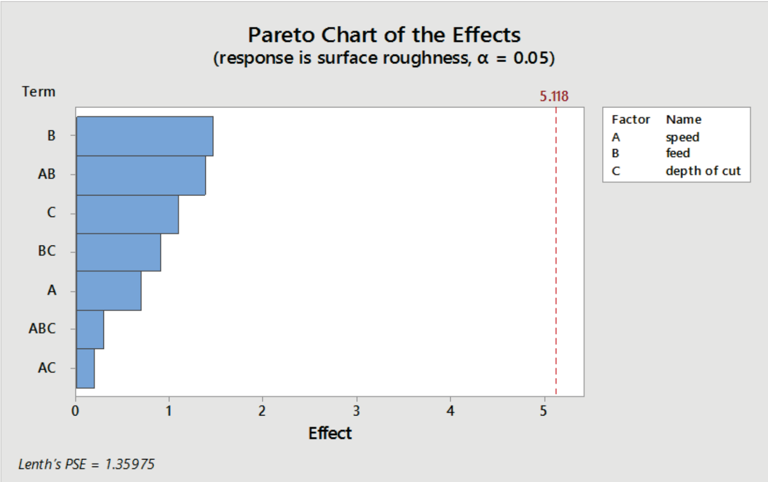

Figure 4. Pareto chart of the effects

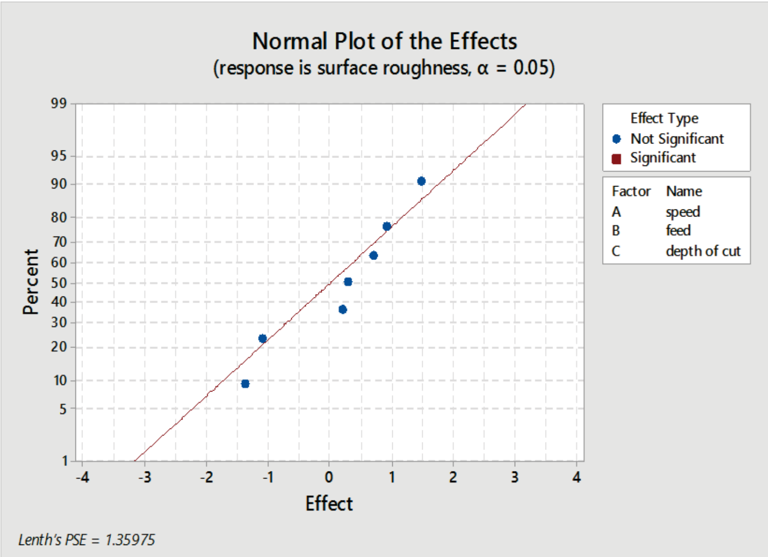

Figure 5. Normal plot of the effects

7. CONCLUSIONS

The analysis of factorial design reveals that feed is the most dominant factor that influences the surface roughness in turning of Al 6351 T6 and next is the interaction between speed and feed. A mathematical equation for surface roughness has been developed for surface roughness by using Minitab 17 software and the intermediate values of cutting parameters are substituted in the surface roughness equation and the experimental value is found to be 11.4965 microns. The percentage error between the experimental values and the actual value is found to be 19.49%.

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