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Influence of turning Treatments on Al6061 by Offline Inspection Technique

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Abstract: Aluminium is mostly extracted from bauxite and is frequently being utilised in the manufacture of sea, land and air vehicles. Since, it has the merit of resistance to corrosion it is frequently being used in sea vehicles. Another outstanding merit of aluminium is its weight which is very less compared to other ferrous materials. In our study, we have selected Al6061 as the material and based on full factorial design the surface roughness has been observed with three base parameters speed, feed and depth of cut. A mathematical model has been developed to predict the surface roughness and also the dominant factor affecting the turning process has been determined. The plots such as main effects, interaction and Pareto chart have been analysed to give an effective conclusion to the process followed in the study. The purpose of these experiments to compare the effect of process treatments in all possible pairs to select the best treatment to the process has been done satisfactorily.

1. Introduction

Aluminium is durable, has sufficient strength and also the weight is less in comparison with any Ferrous material. It is significantly utilised in space, sea and road transportation. It is also used in infrastructure applications. In all mentioned applications turning operation is done on the material. Turning involves a decrease in size of the diameter. Surface finish depends on three treatments to the process for effective output response which is surface finish. A good surface finish results in less friction and wear. If the finish is not good it leads to cracks. Chemical composition of the material used in our present study is Si(0.4%-0.8%), Fe(0%-0.7%), Cu(0.15%-0.4%), MN(0%-0.15%), Mg(0.8%-1.2%), Cr(0.04%-0.35%), Zn(0%-0.25%),Ti(0%-0.15%).Aluminium 6061-T6 is a precipitation hardened aluminium alloy with silicon and magnesium as its major alloying elements. It is one of the most common alloys for general purpose use. It has an ultimate tensile strength of 290Mpa and a yield strength of 240Mpa. It is used in bicycle components, ultra-high vacuum chambers etc. The primary goal of the present work is to determine the dominant factor affecting the turning process and also to develop a mathematical model by design of experiments by the process parameters selected.

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2. Literature Review

The performance reliability and cost depends on surface roughness and lot of research has been done in finding the process parameter that is actually affecting the process. Thamizhanii.S *et al* report that the depth of cut is the most significant factor which increases the surface roughness and feed only comes second to affect the surface roughness. It is also reported that Taguchi technique is used to determine the optimum parameters to minimize the surface roughness [1].The optimisation of machining parameters for turning Al6061 was carried out by Deepak.D *et al* and they found that feed was the dominant factor affecting the process and controlling the surface roughness [2]. M Aruna *et al* report that cutting speed has the surface roughness when machining Inconel 718 using cermet inserts. They further report that surface roughness increases as the cutting speed decreases [3].Narayana Reddy A R *et al* report that speed is the significant influencing factor and feed is the non-influencing factor when coolant is on for machining 20MnCr5 steel alloy. It is also reported that cutting speed is the influencing factor and feed is the non-influencing factor when coolant is off for 20MnCr5 steel alloy [4]. Ulhas K Annigeri *et al* report that rate of feed is dominant turning treatment that has an effect on output response in turning of Al6351 T6. The interaction between speed and feed is the next significant factor [5].G Balasubramanyam *et al* conclude that the speed and feed rate are the most significant factors in the surface roughness model. They have also report that genetic algorithm and particle swarm optimisation provide optimal machining parameters for continuous profile in the machining of S45C OR Equivalent Alloy (1045) [6]. E Daniel Kirby *et al* said that rate of feed has a more influence on the output response of finish than speed and depth of cut. He further concludes that parameter design yields an optimum condition of the turning parameters and also a mathematical model was also developed. The mathematical model was accurate within the limits of the measuring device [7].With the study of Dong Woo Kim *et al* it was concluded that DOE technique and ANOVA are useful in determining the influential factors during machining [8]. Samya Dahbi *et al* report that interaction between feed rate and nose radius has significant effect on finish [9]. N. Radhika *et al* conclude that rate of feed is the influencing treatment for output response which is finish [10].

3. Research Methodology

Design of experiment is an offline inspection technique for effective performance of process and product. This consists of (I) the design of experiment, (II) Conduct of experiment, (III) Analysis of data. A full factorial experiment is one which has a set of factors or more than a set of factors and its experimental procedure takes care of all combinations of these values across all factors. It helps in analysing the influence of a treatment on output and influence of turning treatments interaction. The advantage of this technique is that the economy of the experiment is restored as compared to one factor at a time. Table 1 gives the upper and lower limit of parameters, and table 2 gives the full factorial design.

Table 1. Upper and lower limits of parameters

Speed(RPM)	Feed(mm/rev)	Depth of cut(mm)
2500	0.18	1.5
1500	0.12	1.0

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Table 2.Full Factorial design

Standard order	Run Order	Speed(RPM)	Feed(mm/rev)	Depth of cut(mm)
6	1	2500	0.12	1.5
4	2	2500	0.18	1
1	3	1500	0.12	1
3	4	1500	0.18	1
5	5	1500	0.12	1.5
7	6	1500	0.18	1.5
2	7	2500	0.12	1
8	8	2500	0.18	1.5

The Al6061 specimens are machined in a LL20T L5 lathe machine by turning operation using a single point cutting tool and a coolant. The cutting tool used in this operation is EN 353 hardened material and the lubricant used is 32 grade cutting oil. The specimens are machined under three different turning treatments as reported. A total of eight specimens each of 100mm length and are machined up to a length of 70mm under different combinations of turning parameters. The measured output response of finishes are tabulated and given in table 3. An Extra specimen is also machined with intermediate parameters to validate the mathematical model developed.

Table 3. Measured surface roughness table

Speed(RPM)	Feed(mm/rev)	Depth of cut(mm)	Surface roughness(micro meters)
2500	0.12	1.5	1.114
2500	0.18	1.0	1.351
1500	0.12	1.0	1.110
1500	0.18	1.0	1.389
1500	0.12	1.5	1.030
1500	0.18	1.5	1.228
2500	0.12	1.0	1.225
2500	0.18	1.5	1.252

Figure 1. Machined specimens of Al6061

4. Results and Discussions

The surface roughness values obtained from experiments were input into the Minitab 17 statistical software. It is observed from Figure 2 that feed is the dominant factor on every surface roughness. The figure also shows each factor and their level effect. There is a major change in surface roughness when feed is varied from 0.12 to 0.18. The slope of the line of feed treatment is higher compared to speed and depth of cut as observed from the plot.

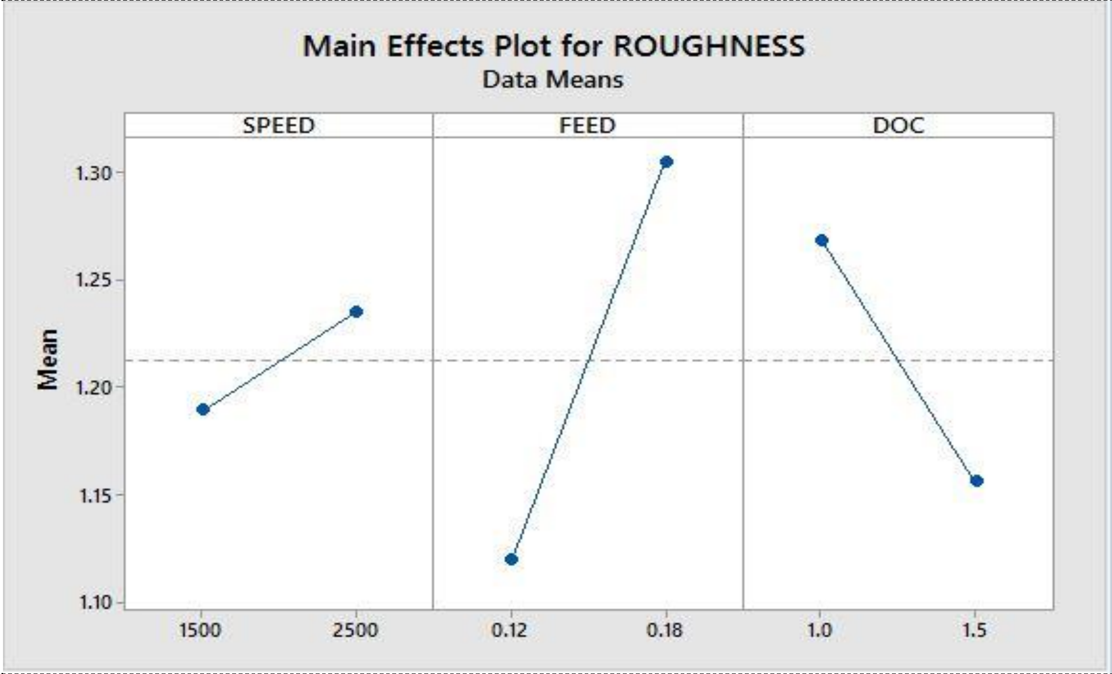

Figure 2. Main Effects Plot

If the two response lines in the interaction plot are approximately parallel then it indicates that there is no interaction effect. In the present study the response lines of speed and feed are not parallel as observed in figure 3. It is to be concluded that for a better output response on Al6061 the interaction between speed and feed is playing a vital role. Pareto chart as shown in figure 4 indicates the result of different parameters based on R_a surface roughness. Pareto chart is for highlighting the important treatment for the output response. There is a reference line having a value of 0.1962 in the chart as depicted. Any parameter that extends beyond this line is potentially important but in the present study both feed and depth of cut are near to the reference line and hence these two parameters are to be considered for better finish while turning Al6061.

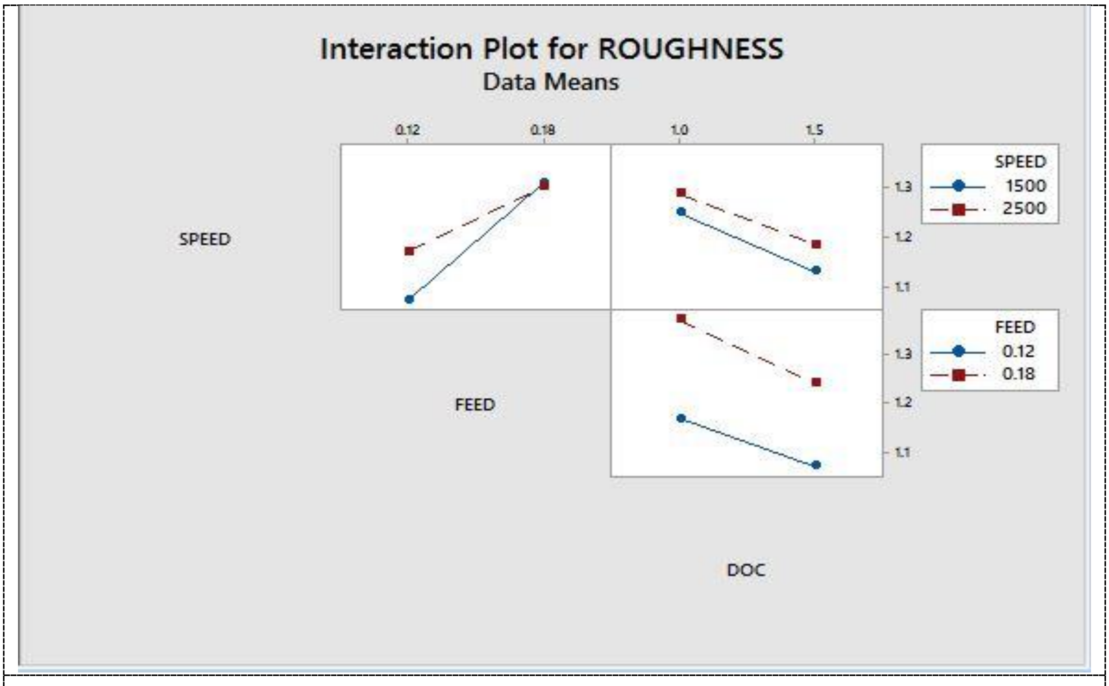

Figure 3. Interaction Plot

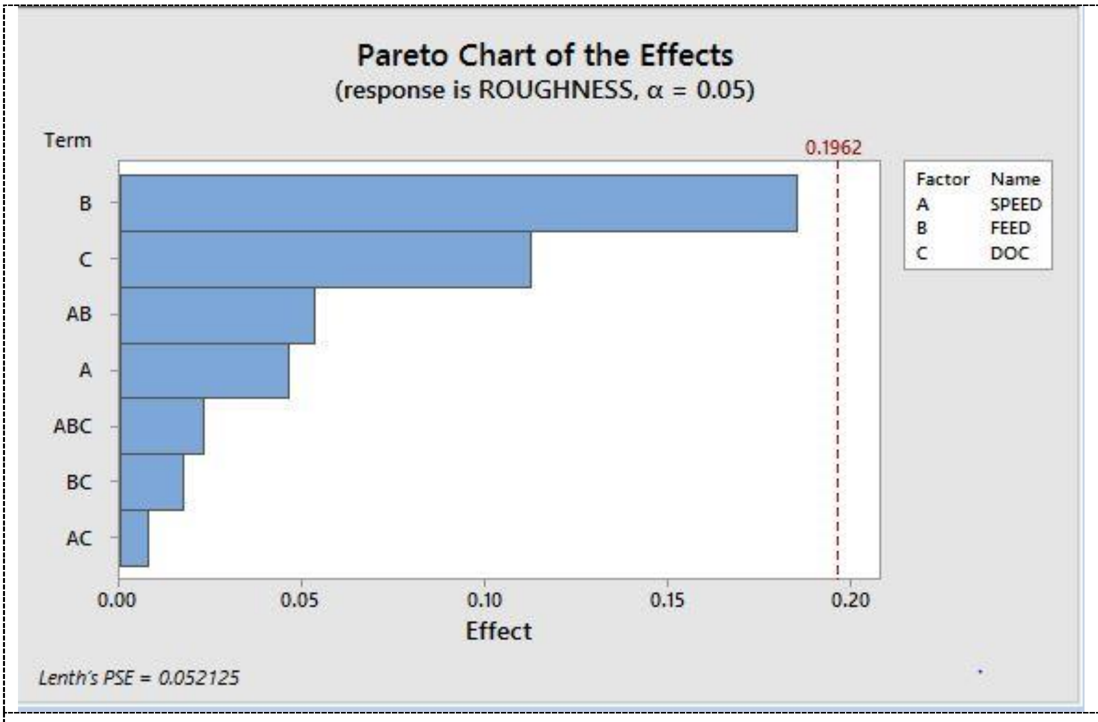

Figure 4. Pareto chart

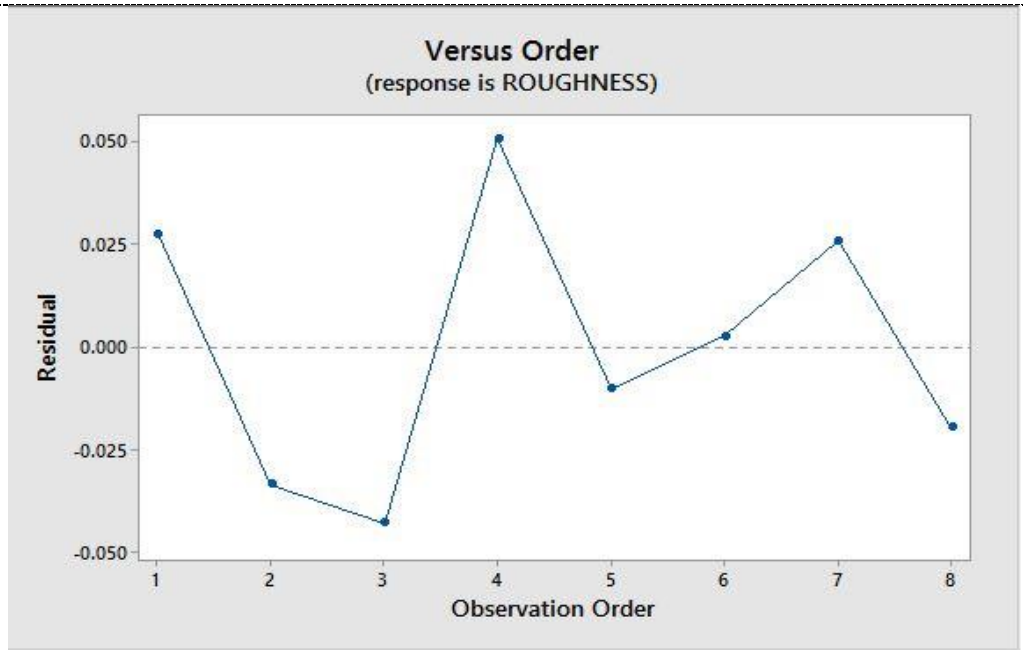

Figure 5. Residuals vs. order for roughness

Figure 5 shows a random scatter of residuals, thus there is no correlation between the residuals and hence there is no violation of independent assumption. Figure 6 shows residuals versus fitted values which is helpful in detecting several common type of model inadequacies. In the present study it is observed that the residuals are contained in a horizontal band and hence there are no obvious model defects.

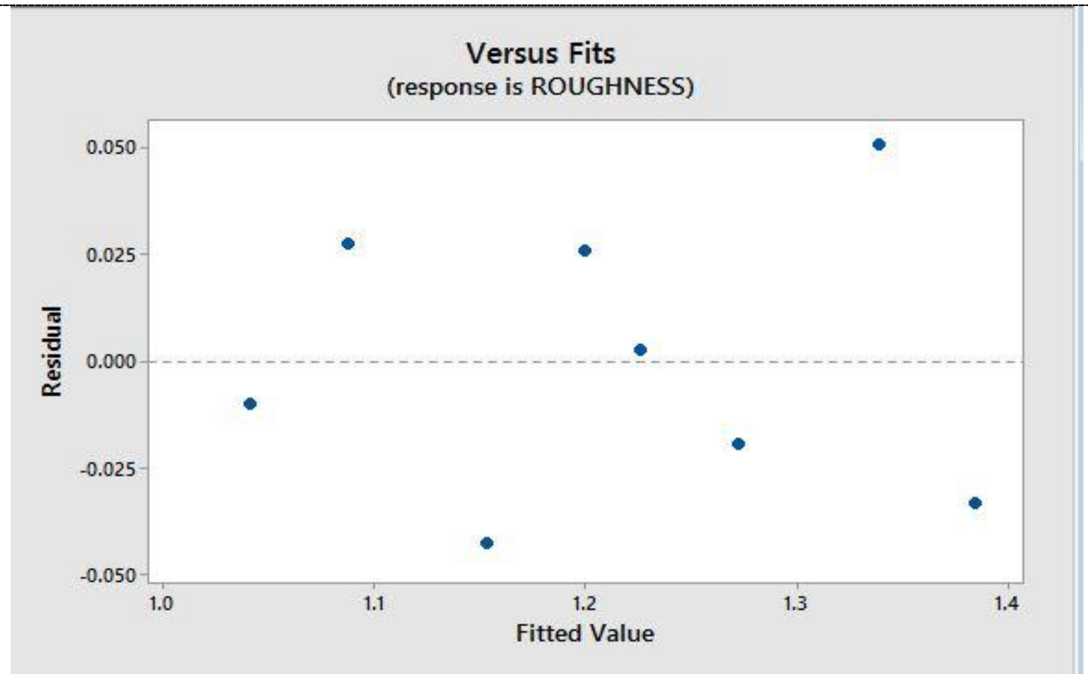

Figure 6. Residuals vs. fits for roughness

The plot of residuals on a normal probability plot should resemble a straight line to check the normality. Figure 7 shows the plot of residuals on the normal probability plot, it can be inferred that errors are normally distributed. In the normal probability plot, the points which are close to the line fitted to the group of points represent factors which do not have any significant effect on the average surface roughness which is the response. Normal probability plot is constructed based on central limit theorem. From figure 7 none of the factors are significant but with the help of Pareto chart and normal probability plot we can decide that feed is one of the factors which can be considered for getting better surface roughness.

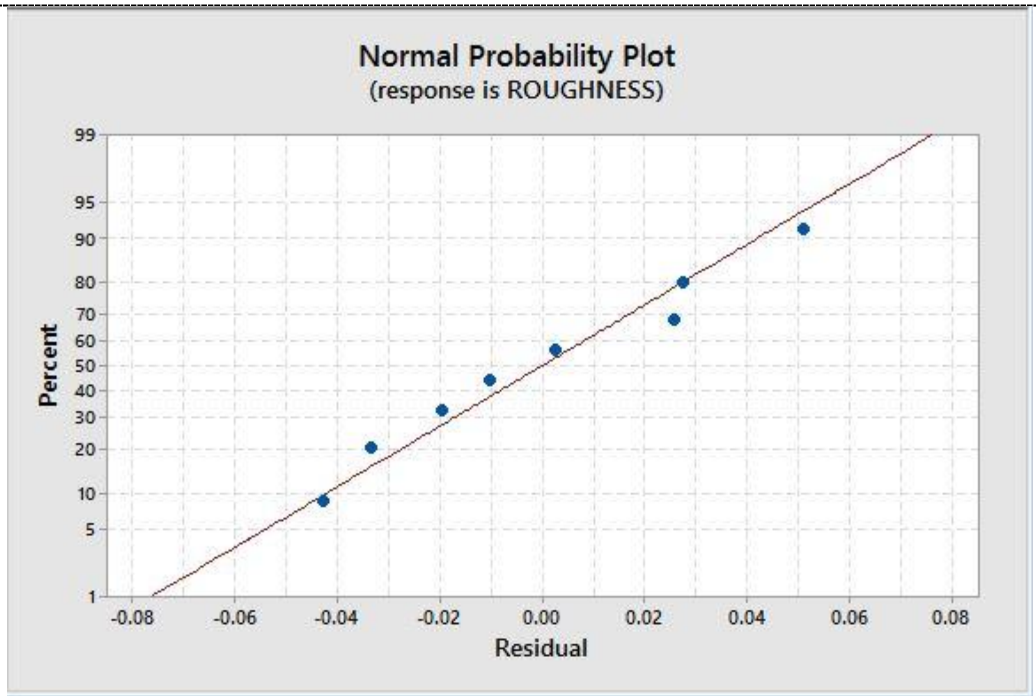

Figure 7. Normal probability plot

Finish is considered as dependent on three parameters of turning as reported earlier.

- Surface Roughness = f(S,F,D)

And hence the equation can be written as,

- Surface Roughness = $Z + Z_1 \times S + Z_2 \times F + Z_3 \times D$

Where,

- Z = Average response Value
- Z_1, Z_2, Z_3 = Coefficients of interaction effects and mean effects

With the help of statistical software a mathematical model has been developed

- Surface Roughness = $0.939 + 0.000046 \times S + 3.087 \times F - 0.2255 \times D$

To check the error between the experimental and the theoretical surface roughness values, the following intermediate parameters of turning have been considered.

Table 4. Experimental values considered

Speed	2000(rpm)
Feed	0.15(mm/rev)
Depth of cut	1.25(mm)

Table 5. Comparison of theoretical and experimental values

Experimental value	Theoretical Value	Error
1.029	1.212	17.78%

There is an error of 17.78% between the experimental value and the theoretical value.

5. Conclusion

It can be concluded that

- Feed is the influential factor which gives us a lesser surface roughness value i.e. more continuous surface profile amongst the three parameters selected while turning Al6061.
- The mathematical model developed is adequate as indicated from the three plots of check for normality, check for independence and residual versus fitted value i.e, from figures 5, 6, 7.
- The interaction between feed and speed is the most prominent interaction among all the interactions and it causes an increase in the surface roughness.

6. Scope for improvement

The scope of improvement in the study would be to use Taguchi technique to find the optimum treatments to get the best output response and also to reduce the error as predicted by mathematical model.

7. References

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