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Effect Of Dry Machining In Turning of Aluminium 6063 T6 alloy

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Abstract- In this study, the effect of the machining parameters like cutting speed, feed, depth of cut on surface roughness are investigated, also optimum process parameters are analyzed. The L9 orthogonal array, analysis of variance (ANOVA) and the signal –to-noise (S/N) ratio are used in this study. Experiments are done on conventional lathe machine. Aluminum Alloy - Al 6061 T6 grade material is used in automotive parts, ATV parts etc. The most significant parameters for surface roughness are speed, depth of cut and least significant factor for surface roughness is nose radius For surface roughness speed, nose radius are the most significant parameters and least significant factor for surface roughness is depth of cut. The mathematical model obtained as a result of regression analysis can be reliable to predict MRR and surface roughness Ra. In this case particularly we analyze dry machining. The optimal machining conditions for 4 slot workpiece were 281.49 m/min speed, feed 0.125 mm and depth of cut 0.5mm
Keywords – Aluminium 6063 T6, Intermittent cutting, Design of Experiment, ANOVA

I. INTRODUCTION

Turning is one such machining process which is most commonly used in industry because of its ability to have faster material removal at the same time produces reasonably good surface finish quality. During turning process, higher values of cutting parameters offer opportunities for increasing output but it also involves a greater risk of deterioration of surface quality and tool life, therefore cutting speed and feed rate are two very important parameters to achieve optimum cutting conditions. Many studies involving different tool materials, cutting parameters, tool geometry and cutting fluids when machining this important aerospace material have been published [1].

From literature review and research issue it is seen that parameters affecting cutting tool materials are cutting speed, feed, depth of cut, tool geometry, tool temperature, and cutting forces. It is also seen that dry–wet conditions affect the cutting tool materials. The ability to machine aluminum dry would have enormous benefits in reduced infrastructure, lower costs and a cleaner environment compared to today's practice of wet machining. However, that goal has been impractical due to the build-up of hot aluminum on tools in the absence of the lubrication and cooling supplied by metal removal fluids [2].

For present study, cutting forces and surface roughness has been taken as performance measures for turning commercial Aluminium 6063 T6 is one of the alloy widely used in manufacturing industries. To determine most significant process parameters in turning commercial Aluminium 6063 T6 alloy under dry environment, establish relationship between significant process parameters and performance characteristics i.e. surface roughness and also determine optimal values for the turning Aluminium 6063 T6 alloy to minimize surface roughness. H.M. Samashekara [3] has developed regression model during machining of Al 6351-T6 Aluminium alloy with the help of uncoated carbide insert to analyze the combination of machining parameter(speed, feed, depth of cut) for better performance within selected range of machining parameter

II. PROPOSED ALGORITHM

2.1 Work Material –

A hollow pipe of Aluminium 6063 T6 alloy steel with 80 mm diameter, 100mm long, is having thickness of 10 mm workpiece (Figure 1). It was found that after hardening scale formation and salt accumulation was done on the shafts. To remove the scale; shafts were turned on lathe machine maintaining the integrity of the specifications.

Experimental set up

Commercially available uncoated carbide tool inserts with geometry of TNMG 160408 ML K10. It is for medium light applications. Used for stainless steel, steel and aluminum. It having Very high positive rake geometry to minimize built-up-edge and cutting forces. Grade K10 is for the excellent wear resistant.

2.2. Methodology –

There are various methodologies by which machining operation can be optimized to improve the quality of a product or process. Widely used approaches in product\process development generally are: 1. Build-test-fix 2.One-factor-at-a-time 3.Design of experiments (DOE). The “Build-test-fix” is the primal approach to conduct the process as per as the resources available, rather than optimize it. On the other hand, the objective of “One factor-at-a-time” approach is to optimize the process by conducting an experiment at one particular condition and repeating the same experiment

2.3. Taguchi Method–

Taguchi developed a particular design of orthogonal arrays to study the entire parameter space with a small number of experiments only.. There are three categories of quality characteristics in the analysis of the S/N ratio, i.e. the lower the better, the higher the better, and the nominal the better. The formula used for calculating S/N ratio is given below[4]

As Smaller the better:

It is used where the smaller value is desired.

S/N ratio (ŋ) = $-10 \ log_{10} \sum \frac{y_i^2}{n}$

Where, y_i = observed response value and n = number of replications. Table -1 showing the ranges of selected factors and levels for the experimentation.

Table -1 Factors and Levels Used in Experiments

Sr. No.		Factors	Levels		
			1	2	3
1	A	Cutting speed (mm/min)	281.49	178.44	113.09
2	B	Feed (mm/rev)	0.16	0.14	0.125
3	C	Depth of cut(mm)	0.7	0.6	0.5

Nominal the best:

It is used where the nominal or target value and variation about that value is minimum

S/N ratio (ŋ) = $-10 \ log_{10} \sum \frac{\mu^2}{\sigma^2}$

where, µ = mean and σ = variance

Higher the better:

It is used where the larger value is desired.

S/N ratio (ŋ) = $-10 \ log_{10} \frac{1}{n} \sum \frac{1}{y_i^2}$

where, y_i = observed response value and n = number of replications.

Taguchi suggested a standard procedure for optimizing any process parameters [4].

2.4. Design of Experiments–

Design of experiment is a powerful tool for modeling and analysis of process variables over some specific variable which is an unknown function of the process variables [4].

Design of experiments (DOE)-

Useful in process development and troubleshooting.

Identifies magnitude of important process and variables effects.

Greatly reduces the number of runs required to perform an experiment. Identifies interaction among process variables.

Useful in engineering design and development.

The present experimental investigation deals with the analysis of the experiment by the Taguchi methodology. A full factorial experiment is better strategy as it is orthogonal. There is equal number of test data points under each level factor. Because of this balanced arrangement other factors does not influence the estimate of a particular factor. In full factorial there is Nf (f is number of factors each at N level) possible combinations that must be tested. Taguchi's design of experiment with a standard orthogonal array L 9 was used because it gave a satisfied result. The L9 OA has nine rows; each row of the matrix represents one trial. However, the sequence in which those trials were carried out was random. Nine experiments with combination of different cutting parameters were randomly repeated. Three levels of cutting speeds, feed rates and depth of cuts were tested. Factors and levels used in the experiment are shown in

In this philosophy, main effective parameters which are assumed to have influence on process results are located at different rows in a designed orthogonal array. With such an arrangement completely and optimized experiments can be conducted. This method is also useful for studying the interactions between the parameters. This method is precise design of experiments tool, which provides a simple, systematic and efficient approach to determine optimal cutting parameters. Compared to the conventional approach to experimentation, this method reduces drastically the number of experiments that are required to model the response function. In Taguchi experimental design, 3 levels of control factors are good enough to handle the problems [4].

To analyse the presence of any non-linearity in the machining experiment 3 levels are considered. Although many factors affect the drilling process, the machining parameters such as spindle speed, feed rate and drill diameter are the important parameters. For the present investigation, only the cutting parameters spindle speed and feed rate are considered. Table -2 shows the drilling parameters are considered, its symbol and its level

III. EXPERIMENT AND RESULT

The researchers have worked upon many facets of hard turning and came up with their own recommendations about the process the details are shown in

Table -2 Conditions For The Cutting Test

Sr. No.	Cutting Condition	Description
1	Workpiece	Aluminium 6063 T6
2	Cutting Inserts	Carbide
3	Diameter of w/p	80 mm
4	Length of W/p	100 mm
5	Hardness	73 BHN
6	Cutting Speed (Vs)	113.09 - 178.44 - 281.49
7	Feed (f)	0.125 - 0.14 - 0.16
8	Depth of cut (DOC)	0.5 -0 .6 - 0.7
9	Cutting Environment (CE)	Dry

The process is essentially a high speed, low feed and low depth of cut finishing process. The cutting speeds, as reported in various works, range between 200 and 800 m/min. Some researchers have reported speeds even higher than these, but most of them adhered to the above range due to stability problems. Feed have been in the range from 0.05 to 0.2 mm/rev. while depth of cut is not more than 4 mm.

Turning experiments were carried out at three different cutting speeds which were 113.09, 178.44 and 281.49 m/min and feed rates were 0.125, 0.14 and 0.16 mm/rev (f) and depth of cut (d) were 0.5, 0.6 and 0.7 mm under dry and wet environment For conducting the experiments, L9 orthogonal array was chosen as shown in Table -3. The performances of aluminium in turning were studied by conducting.

Table -3 L9 Orthogonal Array

Run	Columns		
	1	2	3
1	1	1	1
2	1	2	3
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The Table -1given below is the L9 Orthogonal array which is used for the experiments. The fifty four sets of settings were done to analyze the response that is the surface roughness. Observations are taken according to array design
The results obtained from the experiment were checked with the help of ANOVA, which predicts the significance of the input parameters for any desired response function. It shows the most significant parameter which influences the results. A confidence interval of 95% has been taken for the analysis. It is the most effective tool in optimization techniques
As shown in Table -4total 18 experimental observations we carried out. For this we selected workpieces with different no. of slot to study the effect of it while machining. Selected no. of slots are 4,6 for same shape of material [5]. And for every experiments we can see from the table hat readings are taken for cutting speed, feed and depth of cut.
The main purpose of design of experiment is to optimize the combination of all of the parameters with minimum no. of experimets, so that it is more cost effective technique to get efficient combination and output if the performed experiments. And effect of each trial experiment is observed and further procedure carried out.

Table -4 Experiment Result

Sr. No.	No. of Slots	Vs	F	Doc
1	4	281.5	0.125	0.5
2	4	281.5	0.14	0.6
3	4	281.5	0.16	0.7
4	4	178.4	0.125	0.6
5	4	178.4	0.14	0.7
6	4	178.4	0.16	0.5
7	4	113.1	0.125	0.7
8	4	113.1	0.14	0.5
9	4	113.1	0.16	0.6
10	6	281.5	0.125	0.5
11	6	281.5	0.14	0.6
12	6	281.5	0.16	0.7
13	6	178.4	0.125	0.6
14	6	178.4	0.14	0.7
15	6	178.4	0.16	0.5

16	6	113.1	0.125	0.7
17	6	113.1	0.14	0.5
18	6	113.1	0.16	0.6

3.1. Anova For Surface Roughness–

Results obtained for the machining forces and surface roughness are shown in the The results for machining forces and surface finish were obtained from the 54 experiments performed. The experimental results are analyzed by using ANOVA. The F value calculated through MINITAB 15 software is shown in the second last column of ANOVA table which suggest the significance of the factors on the desired characteristics. In experiment three forces were observed, the radial force, feed force and tangential force. Larger is the F value higher is the significance (considering confidence level of 95%). Response table show the ranks of the various factors. Higher is the rank higher is the significance.

Roughness measurement has been carried out using a surface measuring instrument developed for shop floor use. MAHR SURF M 400, Mahr make is a self-contained instrument for the measurement of surface textures with variety of parameters according to various national and international standards. Surface roughness is determined from the vertical vallyes texture produced during the detector traverse on the surface irregularities. The measurement results are displayed on digitally/graphically on the touch panel, and the output to the built in printer. Initially the instrument was calibrated with the master specimen provided.

Table-5 Results For Surface Roughness

No. of Slots	Speed	Feed	Depth of Cut	Surface Roughness Ra (µm)	
				Trial 1	Trial 2
4	281.5	0.125	0.5	1.86	1.9
4	281.5	0.14	0.6	1.863	1.912
4	281.5	0.16	0.7	2.176	2.2
4	178.4	0.125	0.6	1.929	1.93
4	178.4	0.14	0.7	2.191	2.2
4	178.4	0.16	0.5	2.144	2.166
4	113.1	0.125	0.7	1.909	1.92
4	113.1	0.14	0.5	2.029	2.1
4	113.1	0.16	0.6	2.066	2.12
6	281.5	0.125	0.5	2.039	2.123
6	281.5	0.14	0.6	3.714	3.725
6	281.5	0.16	0.7	2.201	2.215
6	178.4	0.125	0.6	1.898	1.91
6	178.4	0.14	0.7	1.845	1.85
6	178.4	0.16	0.5	2.038	2.12
6	113.1	0.125	0.7	1.956	1.975
6	113.1	0.14	0.5	2.044	2.1
6	113.1	0.16	0.6	2.347	2.32

3.2. Effect Of Cutting Parameters On Surface Roughness–

Surface roughness influences not only dimensional accuracy of machined parts but also their properties. Surface roughness is an important parameter to evaluate the performance of the cutting tools. The irregularity of derived surface is the result of the machining process parameters, including selection of cutting conditions and also environmental conditions. In hard turning process, the surface roughness is greatly affected by a number of factors such as nose radius, work hardness, cutting angles and cutting conditions etc.

3.3. Analysis Of S/N Ratio For Surface Roughness–

Surface roughness type found of “lower is better”, which is a logarithmic function based on the mean square deviation (MSD), given by

$$(\mathrm{S/N})_{LB} = -10 \log (\mathrm{MSD})_{LB}$$

Where, $(\mathrm{MSD})_{LB} = \frac{1}{r}\sum_{j-1}^{r} y^2$

Table 5 shows values of surface roughness. The analysis was carried at a significance of α = 0.05. The main effect is shown in the response table for S/N for forces. In order of significance feed, depth of cut, cutting speed and cutting environment were the most significant factors. Similarly, Table shows the ANOVA calculations for the S/N ratio of surface roughness. The analysis was carried at a significance of α = 0.05. The main effect is shows the response Table 6 for S/N for surface roughness and Table 7 shows response table. In order of significance feed, depth of cut, cutting speed and cutting environment were the most significant factors.

3.4. Analysis Of S/N Ratio For Surface Roughness–

Table -6 Anova For S/N Ratios Of Surface Roughness For 4 Slots

Speed	Feed	DOC	Trial 1	Trial 2	S/N Ratio
3	1	1	1.86	1.9	-5.48365
3	2	2	1.863	1.912	-5.51847
3	3	3	2.176	2.2	-6.80108
2	1	2	1.929	1.93	-5.7089
2	2	3	2.191	2.2	-6.83069
2	3	1	2.144	2.166	-6.66906
1	1	3	1.909	1.92	-5.64114
1	2	1	2.029	2.1	-6.29758
1	3	2	2.066	2.12	-6.41611

Table -7 Response Table For Means Of Surface Roughness For 4 Slot

	A	B	c
level 1	-18.3548	-16.8337	-18.4503
level 2	-19.2087	-18.6467	-17.6435
level 3	-17.8032	-19.8863	-19.2729
difference	-1.40545	-3.05256	-1.62943
Total	-55.3667	-55.3667	-55.3667

3.5. Main Effect Plots For Surface Roughness–

Main effect plots for forces shown in the Figure 2 main effect plot shows the variation of forces with respect to the no. of slots , cutting speed, feed and depth of cut. X axis represents change in level of the variable and Y axis represents the change in the resultant response. The mean line is shown by the straight horizontal line. It

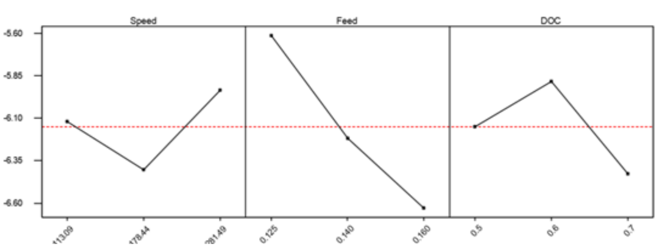

Figure 2. Main Effect Plot For 4 Slots

The best combination values of speed, feed and depth of cut to minimizing surface roughness are:
It observed from figure that surface roughness slightly increases when turning wet environment than dry environment. At lower cutting speed and higher cutting speed, higher surface roughness is observed. At the cutting speed 281.49 m/min. surface roughness are lower. ANOVA table shown by Table -8

Table -8 Analysis Of Variance For SNRA4, Using Adjusted SS For Tests

2	0.33429			
2	0.33429	0.16714	1.69	
2	1.57129	1.57129	0.78565	7.96
2	0.44252	0.44252	0.22126	2.24
2	0.19748	0.19748	0.09874	

As depth of cut 0.6 surface roughness decreases. As feed rate increases the surface roughness decreases and slightly increases. Feed having greater influence on surface roughness compared to cutting speed and depth of cut.

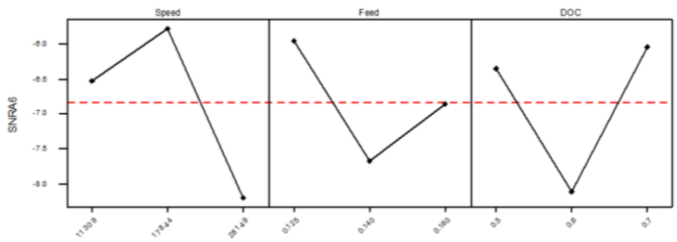

Figure 3. Main Effect Plot For 6 Slots

Interaction effects of cutting speed (Vs), feed rate (f) and depth of cut (DOC) on surface roughness (Ra). With an increase in feed rate or depth of cut, for a given cutting speed, the surface roughness increases as shown in Figure 3. main effect plot for 6 Slots

IV.CONCLUSION

This study involves the application of Taguchi experimental method for investigating the influence of cutting parameters on surface roughness during intermittent cutting of Aluminium 6063 T6. Different factors affecting the surface texture also. Taguchi method based on performance of evaluation or experiments and to test the sensitivity of a of response variables to a set of control parameters by reference to experiments in "orthogonal array" with an objective to attain the optimum setting of the controlling parameters. Orthogonal arrays provide a best set of well-balanced experiments. The relative magnitude of the factor effects are cutting speed, feed rate and depth of cut. A good feel of the relative effect for the different factors is obtained by the decomposition of variance, which is commonly called as analysis of variance (ANOVA). The level of importance of the machining parameters on the surface roughness was determined by ANOVA. Based on this study, the following conclusions can be drawn for the cutting conditions:

From surface roughness values:

1. The optimal machining conditions for 4 slot workpiece were 281.49 m/min speed , feed 0.125 mm and depth of cut 0.5mm.
2. The optimal machining conditions for 6 slot workpiece were 178.44 m/min speed , feed 0.14 mm and depth of cut 0.7 mm.
3. It is observed that as number of slots increases the surface roughness slightly increases.
4. The feed rate has greater influence followed by depth of cut and spindle speed on surface roughness.

V. REFERENCE

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