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Optimization of Turning Parameter for Surface Finish and Material Removal Rate for Aluminum 6061

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Abstract: *Turning is one of the most important machining operation in industries. Turning process is affected by many facto rs such as the, feed rate, depth of cut, geometry of cutting tool, cutting conditions etc. The objective of this project is to optimize the Cutting Parameters for turning of AL-6061 to obtain the required Surface Roughness and Material Removal rate. Also to determine the Cutting Parameters of Cut, Speed, and Feed for optimal Surface Roughness and material removal rate. The turning of Al-6061 is done on CNC lathe. Taguchi design of experiment is used to optimize the multi response in turning operation. For this purpose, we collect the data for surface roughness and various cutting parameters and Experiments are conducted on CNC lathe machine and also the influence of cutting parameters are studied via analysis of variance (ANOVA) approach.*

Keywords: Al-6061, ANOVA, Material Removal Rate, Surface Roughness, Taguchi

I. Introduction

In the Todays globalization world turning is most common of metal cutting operations. To control chip formation the accurate cutting tools and suitable lubrication are used. Types of Turning are Straight turning, Taper turning, Facing, Grooving, Knurl rolling or knurling etc. Currently Aluminum 6061 is a precipitation hardening aluminum alloy which is used for construction, sports equipment, aircraft equipment, bicycle frame, yatch components and small boats.

It is necessary to acquire the desired surface finish for type of application suitable. Surface roughness and Material Removal Rate has become the most significant technical requirement and it is an index of product quality. Speed, Feed and depth of cut three key parameters determine productivity and part quality. And these three are main variable parameters other factors like tool geometry, Machinability, material, coolant, spindle power etc has negligible effect on surface roughness and material removal rate. Hence in this paper this three parameters are considered as sole parameters for machine settings.

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations on surface. If surface roughness values are large, the surface is rough; if they are small, the surface is smooth. Material Removal Rate typically called as MRR is the volume of material removed per minute. [5]

II. Problem Definition

To optimize the Cutting Parameters for turning of AL-6061 to obtain the required Surface Roughness and Material Removal rate. Also to determine the Cutting Parameters of Cut, Speed, and Feed for optimal Surface Roughness and material removal rate. The possible outcomes of this work are:

- Increase in Quality and Productivity of Product.
- Surface roughness vary with applications; accordingly, the different parameters can be implemented depending upon the applications.
- Surface Roughness can be obtained just by the setting the optimal cutting parameters and work can be done by expert or the beginner operator.

III. Literature Survey

Due to the significance of the subject, problems of optimizing parameters in machining, so many number of works published in this area are reviewed as follows:

Md. Tayab Ali et. Al., investigated that for optimization the cutting parameters like spindle speed, feed rate, and depth of cut for minimization of surface roughness and maximization of material removal rate (MRR) in cnc turning of aluminum. orthogonal array is used for experimental trails. The Annona method is used the most significant parameters [1]. In this research work turning operation is performed on AISI 1020 mild steel for cutting speed, feed rate & depth of cut as process parameters and got the optimized value of MRR & SR. The tool used is WNMG332RP carbide insert with a nose radius of 0.8mm. Influence of parameters are determined using S/N ratio and Anova method for Taguchi [2]. It is observed that the authors have stated the effect of speed, feed, and depth of cut on material removal rate, metal surface and tool wear in machining AISI 4320 alloy steel using tungsten carbide tipped cutter. They also observed that speed is the very important factor here followed by feed rate then depth of cut.

[3]. Kiran Varghese et.al. explains the optimization of cutting parameters using Taguchi method in composite materials. The work piece material used is glass reinforced fiber polymer. Cutting forces and surface roughness are considered as two important parameters for optimization. [4]. The optimization of cutting parameter for surface roughness, material removal rate of aluminum LM-26 alloy and investigated the effect of the various parameters like machine tools, cutting tools material, tool geometry and cutting parameters. The experimental setup of turning is carried out and based on the experimental results, S/N and ANOVA analysis performed [5]. Author explains the optimization of turning process parameters for AISI 410 steel using Taguchi method. In this paper, the authors have investigated the parameters affecting the surface roughness produce in turning process for material AISI 410 Stainless Steel [7]. Optimization of process parameters for optimal MRR during turning of Simple Steel bar using Taguchi method and Anova. In this paper authors have used Taguchi method optimizing process parameters namely, cutting speed, feed rates and depth of cut during turning of mild steel bar with TIN-coated carbide tools [8]. The Experimental investigation of process parameters on MRR and Surface roughness in turning operation on CN.C Lathe machine for Mild Steel–E250: IS 2062. Turning operation has been carried out on CNC turning machine for L9 array [9]. The optimization of turning parameters by using Taguchi method for optimum surface finish. Taguchi method and analysis of variance (ANOVA) is employed to develop a turning process model in for EN19 material using BATLIBOI Sprint 16TC CNC lathe using Tin coated tools with the grade of P20.[11]

3.1 Summary

From above research study it is observed that optimization of turning parameter for different metals and alloys had already done but conventional lathe machines were mostly used for machining process. In this project we are using CNC lathe with HSS tool for AL-6061. Also, it is observed that main three turning parameters are spindle speed, feed rate and depth of cut. Other factors like tool and tool geometry, material, machinability, coolent etc are also there but they have very negligible effect on suface finish and depth of cut so we are choosing that three as our turning parameters.

IV. Materials And Machine

4.1 Composition of Work Piece

Aluminum 6061 is a precipitation hardening aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S"

Figure 1. Al-6061 workpiece

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TABLE 1 COMPOSITION OF AL-6061

Element	Weight %
Al	97.9
Si	0.60
Cu	0.28
Mg	1.0
Cr	0.20

4.2 Mechanical Properties of Al-6061:

TABLE 2 PROPERTIES OF AL-6061

Parameter	Value
Density	2.7e-3 g/mm^3
Poisson's Ratio	0.33
Young's Modulus	75 MPa
Yield Strength	48 MPa
Fatigue Strength	83 MPa
Shear Strength	62 MPa

4.3 Cutting Tool

Single Point cutting tool used made of HSS.

4.4 Machine: CNC lathe

The Machine Used is CNC Lathe machine with Siemens Control System. The other information of machine is,
Model : VLM-T- 100
Make : Sine wave Engineering Pvt. Ltd.

Figure 2. CNC Lathe Trainer

V. METHODOLOGY

5.1 Process Parameters and Mean Levels:

The parameter level settings were decided for conducting the experiment, based on a “brain storming session” and also considering the guide lines given in the operator’s manual provided by the manufacturer of the CNC lathe machine. Following table indicates the values of various process parameters and their levels used for the experiments:

The parameter level settings were decided for conducting the experiment. The level of parameters has been selected as per the strength of manufacturing of Al6061 with HSS tools. The parameters are optimal values which can be easily machined by using CNC speed Lathe. The level 1 corresponds to minimum values of parameters. Level 2 and level 3

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are moderate and maximum values. Taguchi method of optimization is used in this paper. The taguchi method is used as optimizing technique for quality improvement of product work. The method in this paper implies for setting of lathe attachments so as to obtain the better surface finish and Material removal rate. Taguchi design of framework and array methodology has been used here which gives out results for multiple experimental results. In this paper the L9 array of taguchi optimization method is used.

TABLE 3 PROCESS PARAMETERS

Levels	Parameters		
	Speed N (RPM)	Feed rate F (mm/min)	Depth of Cut D (mm)
Level 1	800	90	0.5
Level 2	900	135	0.8
Level 3	1000	180	1

5.2 Experimental Procedure

The experimental trials includes the turning of the work piece by using different cutting parameters. The turning is done for nine different sets. Each set consists of different spindle speed, Depth of cut and Feed rate. Taguchi method of L9 orthogonal array technique is used for experimental trials. The common Length of cut is 25mm for all the work piece.

TABLE 4 EXPERIMENTAL SETTINGS

ti	Spindle Speed (Rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Level
1	800	80	0.5	1-1-1
2	800	120	0.8	1-2-2
3	800	160	1	1-3-3
4	900	90	0.8	2-1-2
5	900	135	1	2-2-3
6	900	180	0.5	2-3-1
7	1000	100	1	3-1-3
8	1000	150	0.5	3-2-1
9	1000	200	0.8	3-3-2

5.3 Experimental Trials

Figure 3. Workpeice after machining

VI. Experimental Analysis

6.1 Surface Roughness

The surface roughness varies for each parameter of work piece. This surface roughness is measured by Talysurf Surface Tester.

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Figure 4. Tally Surf Surface Roughness Tester

6.2 Material Removal Rate

The material Removal Rate can be determined by using the following equation,

MRR = [Initial Wt. of work - Final Wt.]/ [Density in gm/cm3 x M/c time] mm3/min (2

6.3 Experimental Analysis:

T ABLE 5 EXPERIMENTAL RESULTS

Job No.	Level	Ra	MRR mm^3/min
1	1-1-1	1.874	598.67
2	1-2-2	1.61	784.57
3	1-3-3	1.853	2924.58
4	2-1-2	1.479	900.71
5	2-2-3	2.512	5623.74
6	2-3-1	2.755	1307.42
7	3-1-3	2.502	6904.38
8	3-2-1	2.822	3149.93
9	3-3-2	2.973	7255.03

VII. Analysis Of S/N Ratio

7.1 Signal to Noise Ratio

The S/N Ratio for surface roughness is considered as smaller the better.

S/N = -10Log10 [Ra2] (3)

The S/N Ratio for Material Removal Rate is considered as larger the better.

S/N = -10Log10 [1/MRR2]

TABLE 6 ANALYSIS OF S/N RATIO

Job No.	Roughness (R)	(S/N)R (Smaller the best)	MRR	(S/N)R (Larger the best)
1	1.874	-5.45539	598.67	55.5438
2	1.61	-4.13652	784.57	57.89261
3	1.853	-5.35751	2924.58	69.32127
4	1.479	-3.39936	900.71	59.09169
5	2.512	-8.00039	5623.74	75.00051
6	2.755	-8.80243	1307.42	62.32827
7	2.502	-7.96575	6904.38	76.78249

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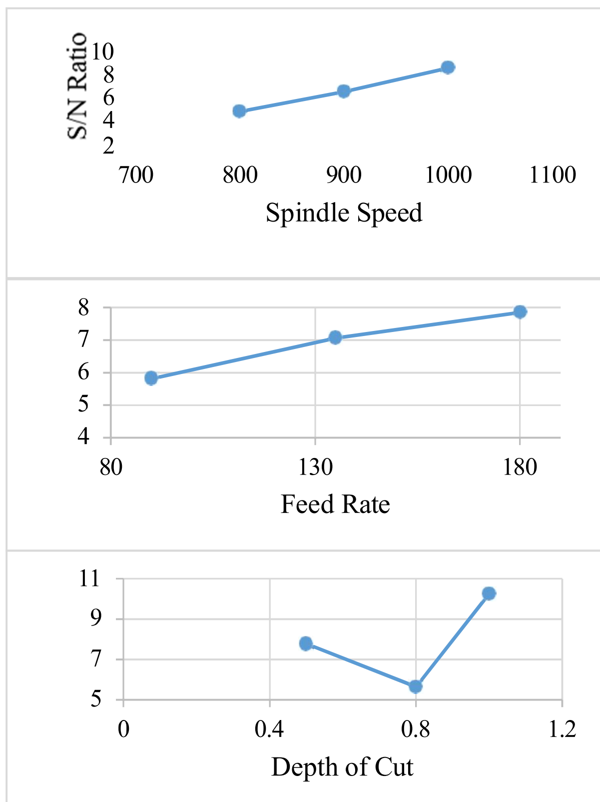
8	2.822	-9.01114	3149.93	69.96601
9	2.973	-9.35808	7255.03	77.21279

7.2 Mean Levels of S/N ratio for Surface Roughness :

TABLE 7: MEAN LEVEL OF S/N RATIO FOR SURFACE ROUGHNESS

Levels	S/N for Surface Roughness Ra		
	For Speed	For Feed	For Depth
Level 1	4.98284	5.80683	7.75632
Level 2	6.73406	7.04935	5.63132
Level 3	8.77832	7.83934	10.2272



Graph 1: Plot Analysis S/.N for Ra

7.3 Mean Levels of S/N ratio for Material Removal Rate :

TABLE 8: MEAN LEVEL OF S/N RATIO FOR MRR

Levels	S/N for MRR		
	For Speed	For Feed	For Depth
Level 1	60.9198	63.8059	62.6123
Level 2	65.4734	67.6197	64.7323
Level 3	74.6537	69.6207	73.7014

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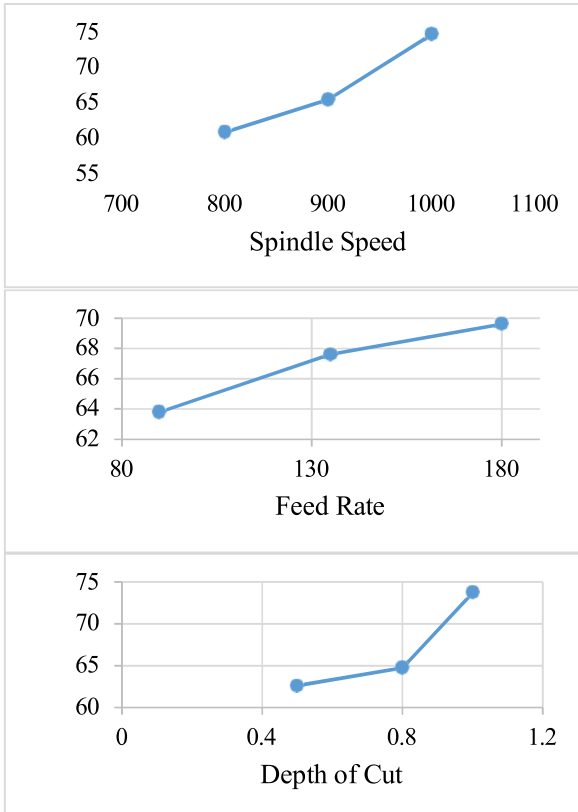

Graph 2: Plot Analysis S/.N for MRR

VIII. Analysis of Variance

Anova is the statistical method which is used to determine the difference between the results, when there are several number of results and groups. In this methodology, there are several groups and results, and there is difference in results, hence Anova technique is used. The ANOVA is carried for each parameter of Speed, Feed and Depth for both roughness and Material removal respectively. The results of Anova shows the most significant parameter for each of roughness and Material removal rate.

8.1 Anova for Surface Roughness (Lower the better)

TABLE 9 ANOVA FOR SURFACE ROUGHNESS

	SST	SSB	SSW	Df1	Df2	P	%
N	40.78	21.64	19.13	2	6	3.39	14.08
F	40.78	7.68	33.09	2	6	0.69	41.62
D	40.78	7.11	33.62	2	6	0.63	43.29

Where,
SST- Total Sum of Squares
SSB- Between Sum of Squares
SSW- Within Sum of Squares
Df1 and Df2-Degree of freedom
P-final value parameter
%-Percentage contribution

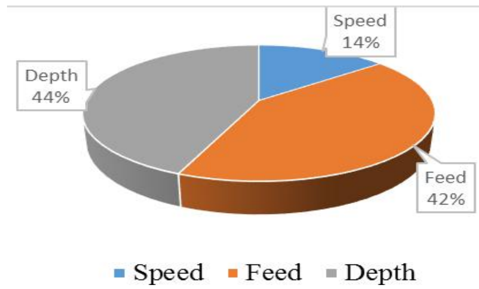

Figure 5 : Contribution of Parameter for Roughness

8.2 Anova for MRR (Larger the better)

TABLE 10 : ANOVA FOR MATERIAL REMOVAL RATE

	SST	SSB	SSW	Df1	Df2	P	%
N	576.7	293.6	283.1	2	6	3.11	61.1
F	576.7	52.3	524.3	2	6	0.29	5.69
D	576.7	207.8	368.8	2	6	1.69	33.2

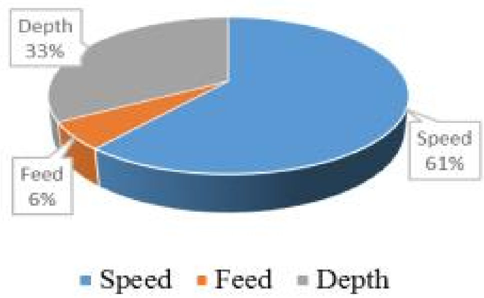

Figure 6: Contribution of Parameter for Roughness

ANOVA with MINITAB 18

Response Table for Signal to Noise Ratios

a. For Surface Roughness

Level	SPEED	FEED RATE	DEFTH OF CUT
1	-4.983	-5.607	-7.756
2	-6.734	-7.049	-5.667
3	-8.814	-7.875	-7.108
Delta	3.830	2.268	2.090
Rank	1	2	3

TABLE 11. MEAN LEVEL OF S/N RATIO FOR SURFACE ROUGHNESS

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Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
SPEED	2	1.4614	57.57%	1.4614	0.730	5.97	0.14
FEED RATE	2	0.5079	20.01%	0.5079	0.253	2.08	0.32
DEFTH OF CUT	2	0.3243	**12.78%**	0.3243	0.162	1.33	0.43
Error	2	0.2447	9.64%	0.2447	0.122		
Total	8	2.5382	100.00%				

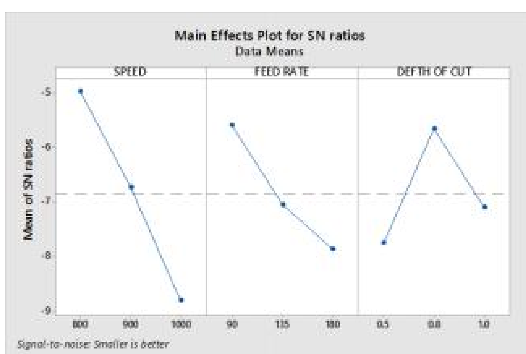
TABLE 12: ANOVA FOR SURFACE ROUGHNESS

we can conclude that we can use Taguchi and ANOVA methodology for determining the significant parameters of cutting. It is Simple and low cost consuming technique

b. For MRR

Level	SPEED	FEED RATE	DEFTH OF CUT
1	60.92	63.81	62.61
2	65.47	67.62	64.73
3	74.65	69.62	73.70
Delta	13.73	5.81	11.09
Rank	1	3	2

TABLE 13 Response Table for Signal to Noise Ratios



Graph 3: Plot Analysis S/.N for surface roughness using MINITAB 18

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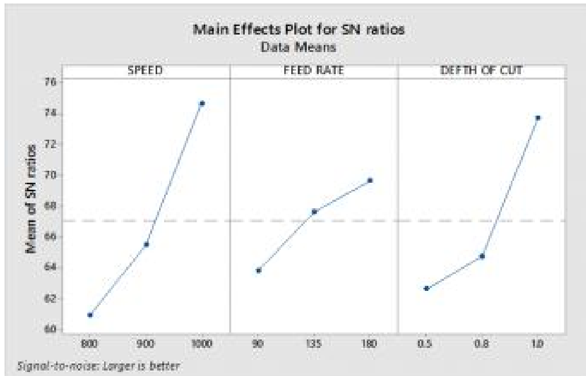

Graph 4: Plot Analysis S/.N for MRR using MINITAB 18

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
SPEED	2	30142321	**52.38%**	30142321	15071160	4.08	0.197
FEED RATE	2	1617734	2.81%	1617734	808867	0.22	0.820
DEFTH OF CUT	2	18398876	31.97%	18398876	9199438	2.49	0.286
Error	2	7382656	12.83%	7382656	3691328		
Total	8	57541587	100.00%				

TABLE 14 ANOVA FOR MRR

Similarly, we can see, by using MINITAB we again get the same result as Speed is important factor as our criteria is larger the best and contribution of speed is smaller as compared to other two factors We can see, by using MINITAB we again get the same result as depth of cut is important factor as our criteria is smaller the best and contribution of depth of cut is smaller as compared to other two factors.

IX. Conclusion

Taguchi method and ANOVA with MINITAB 18 are used for determining the significant parameter for desired surface roughness and Material removal rate. Using lower the best criteria for surface roughness, the most significant parameter is Depth of Cut which impact only 12.78% and using larger the best criteria for material removal, the most significant parameter is Spindle Speed, which impact 52.38%. Hence,

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