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Evaluation of optimum turning process parameters of AA6061-T651 using taguchi method

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Abstract— In Computer Aided Process Planning systems, optimization of process planning parameters is an important field which needs research and development. In the machining processes, achieving good surface quality is also very important in parallel with obtaining accurate dimensions. Machining processes involve a number of process parameters which directly or indirectly influence the Surface roughness. This experimental study is working with Taguchi method for identifying the optimum values of the process planning parameters say spindle speed, feed and depth of cut for the good Surface finish of the cylindrical component during turning operation.

The experimental work is designed using Taguchi's L16 orthogonal array and carried out by turning Aluminium alloy 6061-T651 using Tungsten carbide tool . From the study, it is observed that the surface finish is improved by 42.24 %. The optimal values of machining parameters are estimated using Minitab 16 software. This paper discusses the optimal values of speed, feed and depth of cut for yielding the minimum Surface roughness of the turned product. In addition with the optimal values of the parameters, this paper presents the interactions among these three parameters.

Keywords : Computer Aided Process Planning, Surface Roughness, Turning, Taguchi method

I. INTRODUCTION

Metal removing industries are continuously suffering from the problem of not running the machine tools at the optimum working conditions [8]. Many industrial practitioners and scientists are dealing with the problem of optimization of process parameters.

So, estimating the optimal parametric conditions for a machining operation is mandatory for current industrial situation.

Machining is a process which is used to change the size, shape and surface of a material through removal of materials by straining the material to fracture or by thermal evaporation. In manufacturing industries, turning is a widely used machining operation. Turning is a process in which single point cutting tool removes material from a rotating work piece to form a cylindrical shape.

Aluminium is the least expensive metal that has strong resistance to corrosion. It is easily machinable and has good electrical and thermal conductivities. Aluminum alloy 6061(Al 6061) is widely used in applications like transport and construction where properties such as tensile strength and hardness are required[4]. From the literature reviewed, it is evident that the research gap exists in considering Aluminum alloy 6061 as the work material. In this work, a cylindrical rod Aluminum alloy 6061-T651 is turned using uncoated tungsten carbide tool. Surface roughness (Ra) is a measure of the technological quality of a product and it greatly influences manufacturing cost.

The parameters that affect the surface roughness are spindle speed, feed rate, depth of cut, cutting speed, type of lubricant used, tool angle, tool height, properties of tool used for cutting operation etc.

Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments. The experimental results are transformed into a signal-to-noise(S/N) ratio. The S/N ratio can be used to measure the deviation of the performance characteristics from the desired values. There are three categories of performance characteristics in the analysis of the S/N ratio: the lower-the-better, the higher-the-better and the nominal-the-better. For all the categories of performance characteristic, the largest S/N ratio corresponds to better performance characteristic which means the optimal level of the process parameters is the level with the highest S/N ratio.

This work aims to improve the Surface finish by using the optimal values of the process planning parameters say spindle speed, feed rate and depth of cut with the help of Taguchi Parameter Design Experiment. Minitab 16 is the software used to implement the Taguchi methodology.

II. EXPERIMENTAL DETAILS

A. Work material

The work material used in the study is Al6061-T651 in the form of cylindrical bar of diameter 1 inch.

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Fig 1: Work material-Al 6061 rod

Table 1 : Chemical composition

Al	Mg	Si	Fe	Cu	Zn	Ti	Cr
Balance	0.8-1.2	0.4-0.8	Max 0.7	0.15 -0.4	Max 0.25	Max 0.15	0.04 - 0.35

Table 2: Physical Properties

Density	Melting point	Modulus of Elasticity	Poisson's Ratio
2.7 g/cm^3	Approx	70 – 80 GPa	0.33

Table 3: Mechanical properties

Ultimate Tensil Strength	0.2% Proof stress (Mpa)	Brinell Hardness (500 kg) load	Elongation 50mm dia (%)
260 - 310	240 -276	95 - 97	9 - 13

B. Cutting tool material

The tool used for turning is tungsten carbide of side 12.68mm and thickness 4.89mm.

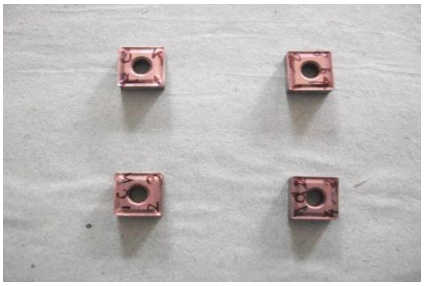

Fig 2: Uncoated tungsten carbide tool

C. Machine tool

Specification of Lathe machine used for turning

Type	:	170 G 2
Size	:	1960
RPM	:	65-1000
Cross slide	:	260 mm

Fig 3: Lathe machine

D. Constraints

This experimental study considers three parameters each with two levels of values.

Table 4: Machining Parameters and their values

Parameter	Level 1	Level 2
Spindle speed(RPM)	290	465
Feed rate(mm/rev)	0.193	0.244
Depth of cut(mm)	0.5	1

E. Experimental design using L16 Orthogonal array

Table 5: Taguchi design for the experiment

S.No	Speed (RPM)	Feed (mm/rev)	Depth of cut(mm)
1	290	0.193	0.5
2	290	0.193	0.5
3	290	0.193	1
4	290	0.193	1
5	290	0.244	0.5
6	290	0.244	0.5
7	290	0.244	1
8	290	0.244	1
9	465	0.193	0.5
10	465	0.193	0.5
11	465	0.193	1
12	465	0.193	1
13	465	0.244	0.5
14	465	0.244	0.5
15	465	0.244	1
16	465	0.244	1

F. Calculation of Surface Roughness

Surface Roughness is measured using Perthometer. The average of the observed values of Surface Roughness (Ra) are tabulated below.

Table 6: Readings observed using Surface roughness tester.

S.No	Speed (RPM)	Feed (mm/rev)	Depth of cut (mm)	Ra (Average) (µm)
1	290	0.193	0.5	1.60
2	290	0.193	0.5	1.60
3	290	0.193	1	1.60
4	290	0.193	1	1.60
5	290	0.244	0.5	2.72
6	290	0.244	0.5	2.72
7	290	0.244	1	2.61
8	290	0.244	1	2.61
9	465	0.193	0.5	1.48
10	465	0.193	0.5	1.48
11	465	0.193	1	2.49
12	465	0.193	1	2.49
13	465	0.244	0.5	2.25
14	465	0.244	0.5	2.25
15	465	0.244	1	2.77
16	465	0.244	1	2.77

III. RESULTS AND ANALYSIS

The input and output parameters of the study are tabulated below.

Table 7: Input and Output parameters

S.no	Input Parameters			Output Parameter
	Speed (RPM)	Feed (mm / rev)	Depth of Cut (mm)	Ra(µm)
1	290	0.193	0.5	1.60
2	290	0.193	0.5	1.60
3	290	0.193	1	1.60
4	290	0.193	1	1.60
5	290	0. 244	0.5	2.72
6	290	0.244	0.5	2.72
7	290	0.244	1	2.61
8	290	0.244	1	2.61
9	465	0.193	0.5	1.48
10	465	0.193	0.5	1.48
11	465	0.193	1	2.49
12	465	0.193	1	2.49
13	465	0. 244	0.5	2.25
14	465	0.244	0.5	2.25
15	465	0.244	1	2.77
16	465	0.244	1	2.77

The Surface roughness is the quality characteristic with the concept of "smaller-the-better".

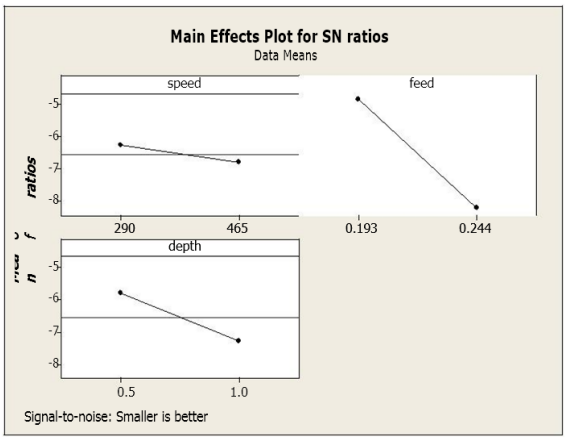

Fig 4: Effect of turning parameters on Surface Roughness for S/N ratio

The regression equation is

Ra = - 2.00 + 0.000657 speed + 15.6 feed + 0.710 depth of cut

Table 8: Table of Coefficients for Regression analysis

Predictor	Coef	SE Coef	T	P
Constant	-1.9966	0.7611	-2.62	0.022
Speed	0.0006571	0.0008611	0.76	0.460
Feed	15.588	2.955	5.28	0.000
Depth of cut	0.7100	0.3014	2.36	0.036

Table 9: Response Table for Signal to Noise ratios

Level	speed	feed	depth of cut
1	6.297	-4.874	-5.806
2	6.806-	-8.229	-7.297
Delta	0.508	3.356	1.492
Rank	3	1	2

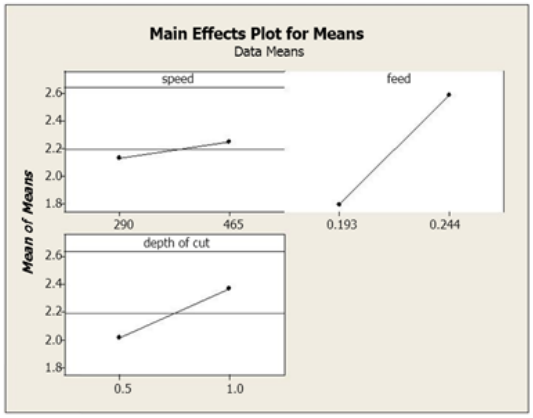

Fig 5: Effect of turning parameters on Surface Roughness for Means

IV. CONCLUSION

1. From the effect of turning parameters on Surface Roughness for S/N ratio(Fig.4), it is evident that the optimal values of speed, feed and depth of cut for the good surface finish of the turned product are 290 RPM,0.193 mm/rev and 0.5 mm respectively.

2. The regression analysis (regression equation and Table 8 clearly states that feed and depth of cut are the parameters which are significantly affecting the surface finish and feed is the most significant factor. When feed increases, surface roughness also increases due to increase in cutting force and vibration. When depth of cut increases, surface roughness increases due to increase in cutting temprature. Increasing the speed helps in improving the surface finish but the speed value is not significantly affecting the surface roughness

3. The Rank values obtained from the response table for S/N ratio values (Table 9) show that the most significant factor is feed and the next significant factor is depth of cut.

4. The interaction plot (Fig.6) reveals that the effect of speed on surface roughness is depending on the values of feed and depth of cut, effect of feed is independent and effect of depth of cut is slightly depending on speed value.

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