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Investigating the Effect of Machining Parameters in CNC Turning Using DOE Technique

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Abstract: In this research, an experimental investigation of the machining parameters of Aluminium Alloy 6063 in CNC lathe machine for turning operation using TNMG115100 tungsten carbide insert had been carried out. In machining operation, the minimum surface roughness and maximum Material Removal Rate are important factors for the better quality of the product and production rate. Thus, the choice of optimized cutting parameters is very important for controlling the required quality. The purpose of this research is focused on the analysis of optimum cutting conditions for minimum surface roughness and maximum material removal rate in CNC turning of Aluminium Alloy 6063 by Taguchi method. The experiment has been carried out based on L9 standard orthogonal array design with three process parameters namely Spindle Speed, Feed rate, Depth of Cut. The experiment results were used to characterize the main factors affecting surface finishing and the material removal rate by Signal to Noise ratio and Analysis of Variance method. The investigations infers that the surface roughness and material removal rate were influenced by the feed rate. It was identified that the Surface roughness decreases with increase in feed rate and MRR increases with related to the feed rate.

Keywords: Aluminium Alloy 6063, CNC Turning, Surface Roughness, MRR, Taguchi Method, ANOVA.

1. INTRODUCTION

Aluminium alloys contain the typical alloying elements, such as copper, magnesium, manganese, silicon and zinc and in which Aluminium (Al) is the predominant metal. Here Aluminium 6063 alloy is taken as work piece material and HSS as cutting tool. The main properties of Aluminium are light weight, strength, recyclability, corrosion resistance, durability, ductility, formability and conductivity, which make them valuable material.

Design of Experiment (DOE) is an influential method to improve manufactured goods design presentation where it can be used to decrease cycle time needed to improve new process. The Analysis of Variance is a powerful statistical tool for test of significance. ANOVA is a separation of variance ascribable to one prove of process of the variance ascribable to the other groove.

Taguchi's Method- Taguchi defines as the product quality should not deviate from its target value. These losses were due to the deviance of the products functional characteristic from its desired target value, and these were called losses due to functional variation. The noise factors which were not controlled, which cause the functional characteristics of a product to deviate from their defined values. The goal of quality engineering was to make products that are robust with respect to all noise factors.

S/N ratios has been calculated in three ways lower is best, higher is best and nominal is best. Depends upon the machining parameters suitable S/N ratio has been selected.

For MRR (Larger is Better),

$$\text{S/N Ratio} = -10 \log \frac{1}{n} \sum_{i=1}^{n} \frac{1}{y^2}$$

For Ra (Smaller is Better),

$$\text{S/N Ratio} = -10 \log \sum_{i=1}^{n} y^2$$

Where,

"y" is the experimental data at ith trial and "n" is the number of trials.

2. MATERIALS AND METHOD)

The materials used in this experimentation were discussed below and the method adopted for experimentation is illustrated clearly.

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2.1 Work Piece Material

In this research work, AA6063 is used as a material. The properties of AA60663 is clearly shown in the below Table 1 & 2.

Elements	%
Si	0.3 – 0.6
Fe	0.15 - 0.35
Mn	0.15
Mg	0.6 - 0.9
Zn	0.15
Ti	0.1
Cr	0.05
Al	Balance

Table 1: Chemical Composition of AA6063

Tensile Strength	220 Mpa
Elongation	5%
Proof Stress	190 Mpa

Table 2: Mechanical Properties of AA6063

2.2 Experimental Setup

The experimental work was carried out on CNC turning center JOBBER XL using high speed steel drill bit. Figure 1 clearly shows the experimental set up of CNC turning center. The specifications of the machine are given in Table 3.

Machine Type	JOBBER XL
Year	2012
Supply Voltage	380V/415V
Control Voltage	24V D.C
Back Up Fuse	63 AMPS

Table 3: CNC Turning Center Specification

Figure 1: CNC Turning Center – JOBBER XL

2.3. Turning Tool

The tool used for this research is TNMG115100 tungsten carbide insert.

Figure 2: Tungsten Carbide insert

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In this work each factor has three levels. L9 orthogonal array is followed. The process parameters and their levels are given in the Table 4.

S.No	Parameters	Levels		
		1	2	3
1	Speed (rpm)	1200	1600	2000
2	Feed (mm/min)	0.10	0.15	0.17
3	Depth of Cut (mm)	0.4	0.5	0.6

Table 4: Process Parameters and their Levels

Cutting Speed (rpm)	Feed rate (mm/min)	Depth of Cut (mm)	Surface Roughness (µm)	MRR (mm^3/min)	S/N Ratio for SR	S/N Ratio for MRR
1200	0.15	0.2	2.4	57	-7.60	35.12
1200	0.3	0.4	1.2	56	-1.58	34.96
1200	0.45	0.6	1.6	48	-4.08	33.62
1600	0.15	0.4	2.7	43	-8.63	32.67
1600	0.3	0.6	1.4	58	-2.92	33.62
1600	0.45	0.2	1.8	46	-5.11	33.26
2000	0.15	0.6	0.76	55	2.38	34.81
2000	0.3	0.4	1.25	42	-1.94	32.46
2000	0.45	0.2	0.92	47	0.72	33.44

Table 5: Experimental values for SR and MRR

2.4. MRR and Surface roughness Measurement

Material removal rate (MRR) has been calculated from the difference of weight of work piece before and after the experiment.

$$MRR = \frac{\pi}{4} . d^2 . l \ mm^3/min$$

Where, d= hole diameter

l= length of the work piece

The surface roughness value machined surface was measured on the surface roughness tester SJ-201(MITUTOYO Model). The surface roughness value was found by 4mm cut-off distance and average value is taken.

3. RESULTS AND DISCUSSION

The purpose of this work is to optimize the turning parameters (spindle speed, feed rate and depth of cut) to achieve low value of the surface roughness and high material removal rate. Taguchi method used for analyzing data offers two advantages; it offers guidance for choosing the optimum level parameter and the other one is comparison of two sets of experimental results.

Level	Cutting Speed	Feed rate	Depth of Cut
1	-4.4234	-4.6159	-3.9951
2	-5.5518	-2.1481	-4.0497
3	0.3899	-2.8212	-1.5404
Delta	5.9417	2.4678	2.5093
Rank	1	3	2

Table 6: Response Table for SR

Table 6 and Table 7 shows the response table values. Cutting speed is influencing towards the machining performance for lower surface roughness and maximum material removal rate.

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Level	Speed	Feed	Depth of cut
1	34.57	34.20	33.94
2	33.18	33.68	33.37
3	33.57	33.44	34.02
Delta	1.39	0.76	0.65
Rank	1	2	3
1	34.57	34.20	33.94

Table 7: Response Table for MRR

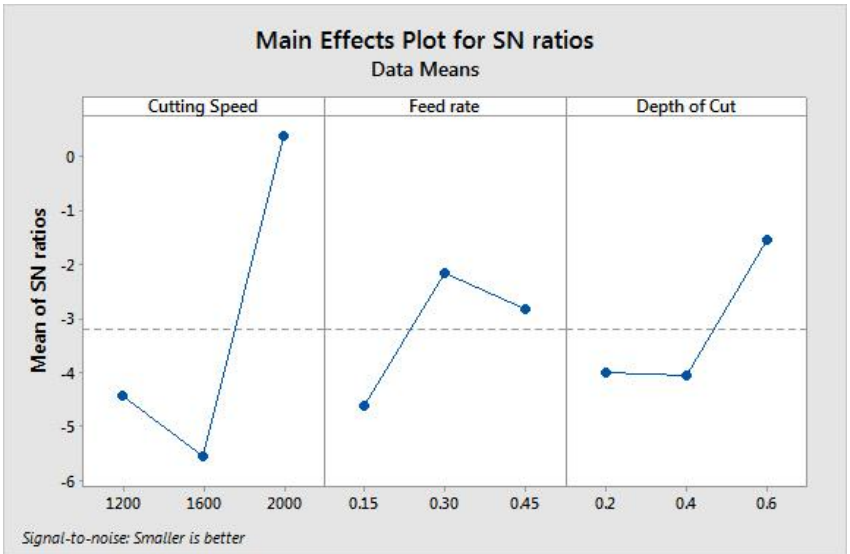

Figure 3: Main effect plots for Ra

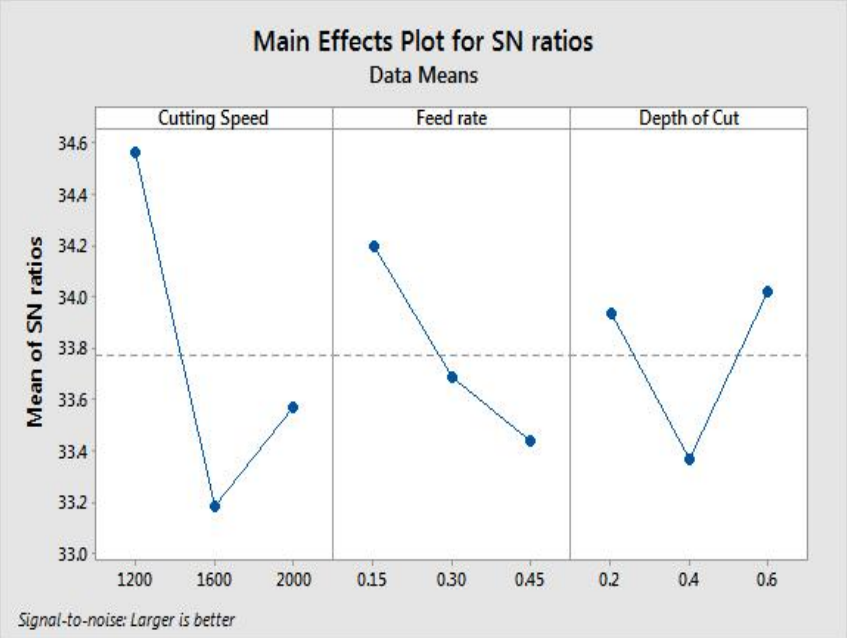

Figure 4: Main effect Plot for MRR

3.1 Analysis of Variance (ANOVA)

Taguchi method will not deliver any details about the influencing parameters So, the contribution of each parameter can be determined by ANOVA. Minitab 17 software is one of the statistical software used for the analysis of influence of parameters.

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Source	DF	SS	MS	F-Value
Speed	2	1.6071	0.8035	2.84
Depth of cut	2	0.7722	0.3861	1.36
Feed	2	0.4555	0.2278	0.81
Error	2	0.5657	0.2829	
Total	8	3.3653		

Table 8: ANOVA for Surface Roughness

Source	DF	SS	MS	F-Value
Cutting Speed	2	101.56	50.78	1.65
Feed	2	65.69	32.84	1.07
DOC	2	52.36	26.18	0.85
Error	2	61.42	30.71	
Total	8	248.89		

Table 9: ANOVA for MRR

From surface roughness analysis ANOVA (Table 8), F-value (2.84) indicates that Cutting speed is contributing more for minimum surface roughness. From MRR analysis ANOVA table (Table 9), F-value (1.65) of parameter shows that cutting speed is contributing more for MRR.

4. CONCLUSION

Taguchi method had been implemented for optimizing multi-response process parameters for CNC End Turning Al 6063 Alloy with L16 orthogonal array. From Table 6, Table 8, and Figure 3, cutting speed is the most influencing parameter for minimum surface finish which is followed by depth of cut and feed rate.From Table 5, superlative parameters found for minimum surface finish machining are feed rate= 0.15mm/min, cutting speed = 2000rpm and depth of cut= 0.6mm. From Table 7, Table 9 and Figure 4, cutting speed is the most influencing parameter for material removal rate which is followed by feed and depth of cut.From Table 5, best parameters found for maximum MRR are feed rate= 0.3mm/min, cutting speed = 1600rpm and depth of cut= 0.6mm. Results got from Taguchi method precisely matches with ANOVA and confirmation test results are also matched with the predicted results.

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