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EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETERS EFFECTON MATERIAL REMOVAL RATE DURING TURNING OF ALUMINIUM-6063 USING TAGUCHI APPROACH

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ABSTRACT

In any machining process, apart from obtaining the accurate dimensions, achieving a good product quality is also desirable. A machining process involves many process parameters which directly or indirectly influence the quality of the product. This study aims an analysis of cutting parameters spindle speed (1500, 2500, 3500 rpm), feed(0.15, 0.25, 0.35 mm/rev), depth of cut (0.1, 0.3, 0.6 mm) in CNC machine of Aluminium 6063. An L 27 orthogonal array is used to study the analysis of variance (ANOVA) and the signal-to-noise (S/N) ratio. Taguchi's technique used for maximizes the material removal rate in machining Aluminium Alloy 6063. Experiments were conducted based on the established Taguchi's technique L27orthogonal array and Minitab-16 statistical software is used togenerate the array.

Keywords: ***Taguchi, ANOVA, Aluminium-6063, Material Removal Rate, Turning.***

I. INTRODUCTION

In a global competitive environment modern machining technologies have been used with the aim to decrease the machining cost and increase the quality of machined parts/components.so it is required to analysis all the parameters incorporated with the machining process. When a sufficient amount of material is to be removed from the work piece turning has been chosen one of the machining process in which a single point cutting tool removes unwanted material from the surface of a rotating cylindrical work piece.The machining time reduces lead to reduce overall costs which depend on volume of material to be removed and machining parameters like spindle speed, feed and depth of cut.

The main objective of this paper is to optimize the material removal rate for the given set of input parameters. An experimental investigation approach was carried out to obtain the optimal value of material removal rate. The Taguchi design approach is utilized for experimental planning and ANOVA is employed to investigate the influence of depth of cut, feed rate and spindle speed on the material removal rate during turning on CNC machine. Taguchi approach is utilized because it is difficult to analyze all the input parameter simultaneously. One factor at one time approach gives influence of one factor on output. Due to ANOVA it is easy to find the significance of each factor and also the interactions of input parameters on output. The results obtained from the experimental study are used to analyzing and evaluating the effects of various input parameters (spindle speed, feed rate, and depth of cut)onmaterial removal rate. The mathematical model is developed by means of multiple

linear regression analysis for optimal selection of machining parameters for maximum material removal rate during machining of Aluminium-6063.

II. EXPERIMENTAL DETAILS

2.1 Work Material

The turning of Aluminium 6063 was done during designed experiments .Aluminium has good machining characteristics such as light weight and good surface finish can be achieved. Table given below shows themechanical properties and composition and Aluminium 6063.

Table 1- Chemical Composition and Mechanical Properties of Aluminium-6063

Chemical		Mechanical Properties	
Component	Amount (wt. %)		
Aluminum	97.5	Ultimate Tensile strength (Mpa)	241
Magnesium	0.45-0.9	0.2% Proof Stress (MPa)	240-276
Silicon	0.2 – 0.6	Brinell Hardness (500g load, 10mm ball)	73
Iron	Max. 0.35	Elongation 50mm dia (%)	9-13
Copper	Max 0.1	Density: g/cm^3	2.7
Zinc	Max. 0.1	Melting Point: Approx	616-654°C
Titanium	Max. 0.15	Modulus of Elasticity:	68.9 GPa
Manganese	Max. 0.1	Poissons Ratio	0.33
Chromium	0.1	Co-Efficient of Thermal Expansion (20-300°C) m/m.°C	23.5x10-6
Others	0.05	Thermal Conductivity W/m.K	200

2.2 Physical Properties

- Density: 2.7 g/cm^3
- Melting Point: Approx 616-654°C
- Modulus of Elasticity: 68.9GPa
- Poissons Ratio: 0.33

2.3 Process Variables and Their levels:

In this study, cutting experiments are planned using Taguchi design of experiment approach. Cutting experiments are conducted considering three cutting parameters: spindle speed (rpm), Feed rate (mm/rev), Depth of Cut (mm) and Overall 27 experiments were carried out. Tablebelow indicates the values of various parameters used for experiments:

Table 2 Input Variables

Parameters and their symbols	1	2	3
A: Spindle Speed (X1, rpm)	1500	2500	3500
B: Feed (X2, mm/rev)	0.15	0.25	0.35
C: Depth of cut (X3, mm)	0.1	0.3	0.6

2.4. Output Variable

This experimental study was carried out to investigate the effect of process parameters (input variables) on material removal rate (output).

2.5 CNC Lathe Machine and Cutting Tool Specifications

Type - Jobber XLCNC Lathe

Controller-Fanuc

Spindle Power -400V, 3.4Amp

Speed Range - 50-4500 Rpm

Insert specification- CNMG 120408 EN-TM

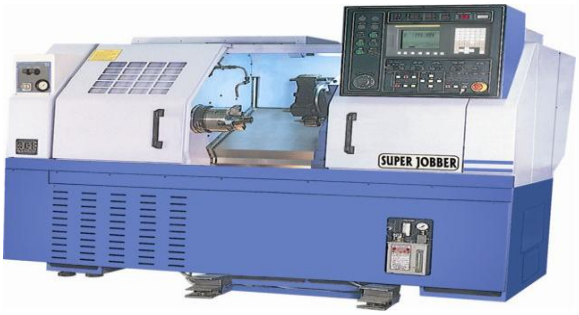

Fig 1: CNC Experimental Setup

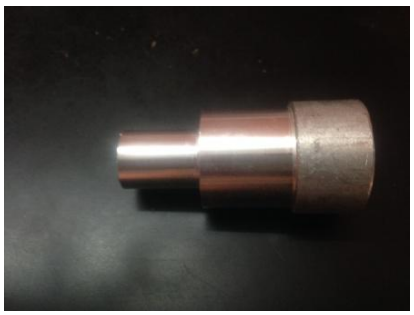

Fig 2: Picture of Finished Work Piece

2.6 Experimental Conditions

After design of experiment the CNC machine was prepared for experimentation the experimental conditions are given below in table3.

Table 3 Experimental Conditions for Turning

Workpiece material	Aluminum 6063 (T6)
Insert designation	CNMG 120408 EN- TM (H20TI)
Spindle speed (rpm)	1500,2500,3500
Feed(mm/rev)	0.15,0.25,0.35
Depth of cut(mm)	0.1,0.3,0.6
Environment	Dry

III. DESIGN OF EXPERIMENT AND EXPERIMENTAL PLANNING

3.1 Orthogonal Array Selection

An orthogonal array has been selected using Taguchi orthogonal array selection technique. The orthogonal array selected should have greater degree of freedom as compare to degree of freedom required. In this analysis an interaction analysis was also done to get the significance of interaction of two variables on output. So L_{27} was selected as design of experiment.

3.2 Experimentation and Process Followed

To perform experimentation 27 pieces were cut from anAluminium 6063 rod each of length 55 mm. weight of each sample was noted using electronic balance model ANAMED AA2000. Then the naming of sample was done according to design of experiments. The prepared samples were machined using CNC machine. The

machining time in each sample turning case was noted carefully. After completion of machining the weight of each sample was measured again and the MRR was obtained. An analysis of S/N Ratio and ANOVA was performedusing MINITAB 16.

IV. RESULTS

A series of experiments have been carried out with variation of different parameters. After completing the experiments according to design of experiment a statistical analysis was done for the experimental data obtained which are shown in table from the L_{27}experiments. The average performance and S/N ratio were calculated for Material removal rate. Analysis of variance (ANOVA) was performed to identify the most significant control parameter and to quantify their effects on material removal rate.

Table 4: Material Removal Rate and S/N Ratio According to Design of Experiment

Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)	MRR (mm^3/min)	S/N ratio MRR
1500	0.15	0.1	444.9225	52.9657
1500	0.15	0.3	597.0095	55.5196
1500	0.15	0.6	643.916	56.1766
1500	0.25	0.1	1862.53	65.4021
1500	0.25	0.3	1937.868	65.7465
1500	0.25	0.6	2132.782	66.5789
1500	0.35	0.1	3263.912	70.2748
1500	0.35	0.3	3368.588	70.5490
1500	0.35	0.6	3487.732	70.8509
2500	0.15	0.1	1158.049	61.2745
2500	0.15	0.3	1193.526	61.5366
2500	0.15	0.6	1305.74	62.3171
2500	0.25	0.1	4193.411	72.4513
2500	0.25	0.3	4387.387	72.8441
2500	0.25	0.6	4417.551	72.9036
2500	0.35	0.1	7256.772	77.2149
2500	0.35	0.3	7264.748	77.2244
2500	0.35	0.6	7473.662	77.4707
3500	0.15	0.1	1752.727	64.8743
3500	0.15	0.3	1807.503	65.1416
3500	0.15	0.6	1930.217	65.7121
3500	0.25	0.1	6476.229	76.2264
3500	0.25	0.3	6565.206	76.3450
3500	0.25	0.6	6692.92	76.5123
3500	0.35	0.1	11214.93	80.9959
3500	0.35	0.3	11290.91	81.0546
3500	0.35	0.6	11423.12	81.1557

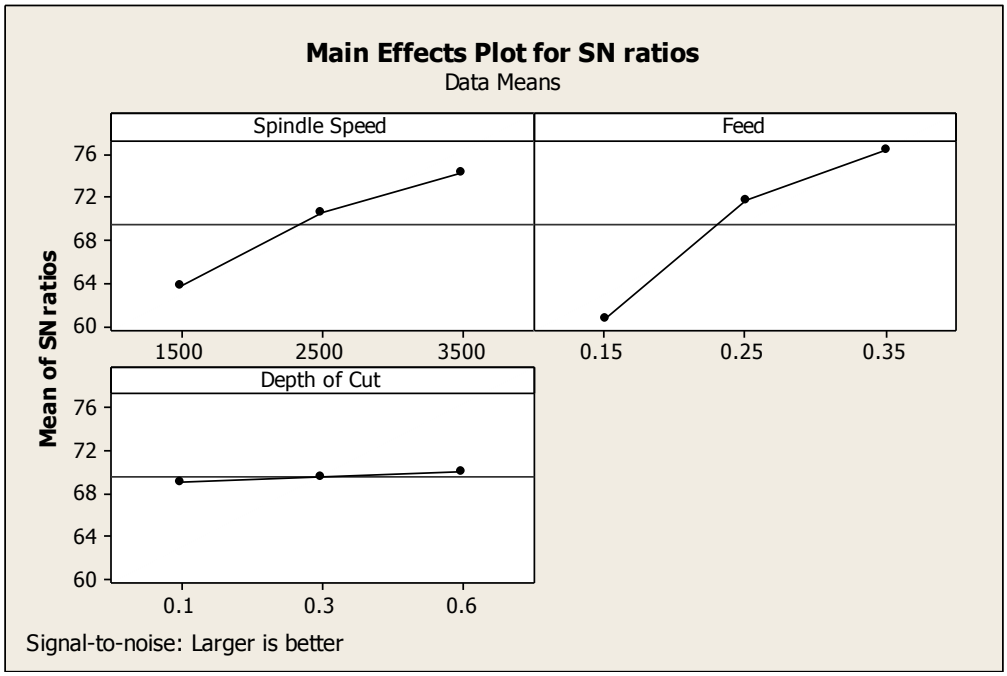

Fig.3S/N Response Graph for MRR

Table-5ANOVA for MRR

Source	Degree of freedom	Seq SS	Adj SS	Adj MS	F	P	% contribution
Speed	2	95289827	95289827	47644913	27645.96	0.000	31.95385
Feed	2	169349860	169349860	84674930	49132.62	0.000	56.78864
Doc	2	198955	198955	99477	57.72	0.00	0.066716
speed*feed	4	33351297	33351297	8337824	4838.02	0.000	11.1838
speed*doc	4	1583	1583	396	0.23	0.914	0.000531
feed*doc	4	5478	5478	1369	0.79	0.561	0.001837
Error	8	13787	13787	1723			0.004623
Total	26	298210787					100

V. MATHEMATICAL MODEL AND COMPARISON GRAPH MATERIAL REMOVAL RATE

The mathematical model is developed by means of multiple linear regression analysis for optimal selection of machining parameters for maximum material removal rate during machining of Aluminium-6063. Equation 1 shows the mathematical model obtained from the multiple regression analysis.

$$Y_{MRR} = 881.707 - 1.74424\ X_1 - 9895.86\ X_2 + 416.781\ X_3 - 2.27037e\text{-}005\ X_1^2 - 2521\ X_2^2 - 65.9168\ X_3^2 + 16.6701\ X_1 \times X_2 - 0.0268944\ X_1 \times X_3 + 461.195\ X_3 \times X_2 \quad \text{----------(1)}$$

Where, X_1 = Speed (rpm), X_2 = Feed (mm/rev)andX_3= Depth of Cut (mm)

Figure 4 shows the graphical representation of the mathematical model (eq.1) and experimental results obtained from 27 sets of experimental investigation.

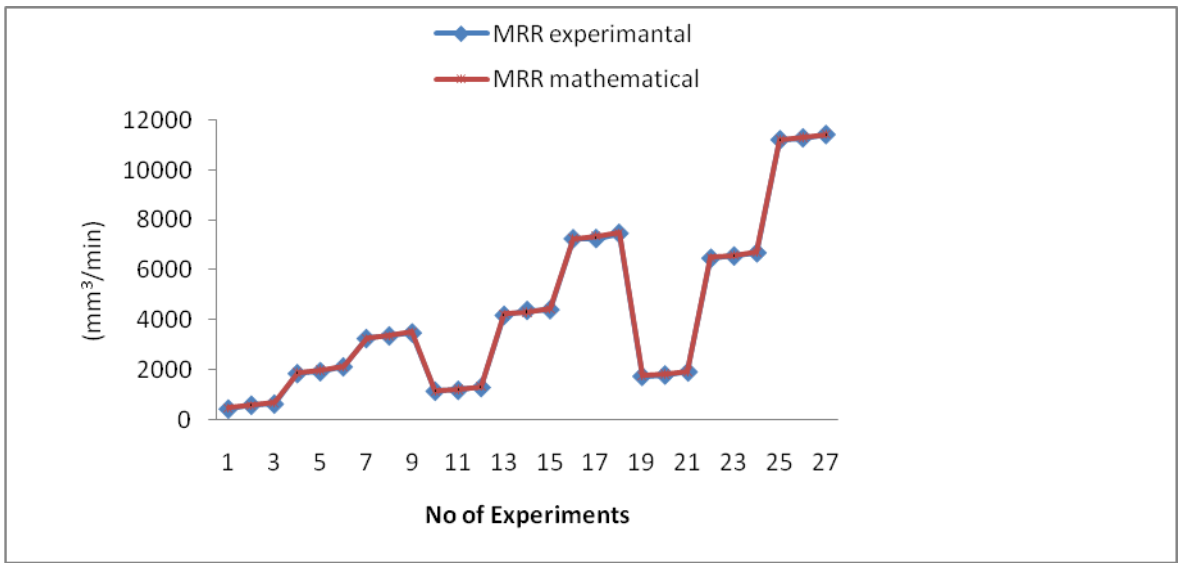

Fig. 4 Comparison of MRR for Aluminum 6063 by Experiment and Mathematical Model

IV. CONCLUSIONS

On the basis of the experimental results during machining on Aluminium 6063 utilizing the CNC machine and thereafter discussion on the investigated results, the following conclusions are drawn as listed below.

(1) The feed has a most significant effect on Material removal rate with 56.78% contribution, speed has 37.95% contribution.

(2) Interaction of feed and speed has a significant effect on Material removal rate with is 11.18% contribution.

(3) For maximum material removal rate, the optimal parametric combination is $A_3B_3C_3$ i.e. material removal rate is maximum at the parametric combination of 3500 rpm spindle speed, .35 mm/rev feed and 0.6 mm depth of cut.

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