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RESEARCH ARTICLE

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MULTIOBJECTIVE OPTIMIZATION OF MACHINING PARAMETERSFOR C-65 MATERIAL USING TAGUCHI & GREY ANALYSIS

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ABSTRACT

CNC machines lead a major in a manufacturing industry, machining comprises of wide variety of operations with turning operation being the most important one. In turning operation performance specifications of concern include surface finish, material removal rate& tolerance which are mostly affected by different machining parameters like machining condition, work piece, tool geometry and operating parameters. Among all of them operating parameter and tool geometry is the most important parameter for better surface finish. This project presents the optimization of various operating parameters as velocity, feed and depth of cut for proper selection of tool inserts for surface finish. The experiment was conducted on CNC lathe with C-65 shaft material. Taguchi's statistical analysis was employed for single optimization as it provides an effective method for product designing which operate continuously over varying conditions surface roughness and depth of cut is the most effective parameter for material removal rate. Best parameter combinations for optimum surface roughness are speed (A) at level 2 (191 m/min), feed (B) at level 1 (0.2 mm/rev), depth of cut (C) at level 3 (1.5 mm), for optimum material removal rate are speed (A) at level 3 (254 m/min), feed (B) at level 3 (0.3 mm/rev), depth of cut (C) at level 3 (1.5 mm). GRGoptimum parameters for SR and MRR are Speed (A) at level 2 (191 m/min), feed (B) at level 1 (0.2 mm/rev), depth of cut (C) at level 3 (1.5 mm

Keywords: Taguchi Method, Machining Parameters, Grey Relation Analysis, Analysis of Variance, C-65 Steel.

1. INTRODUCTION

The main purpose of Taguchi method is reduction of the variation in a process through robust design of experiments. Developed by Dr. G. Taguchi of Japan. the experimental design involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varied; it allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. Analysis of variance on the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic.

2. OBJECTIVE

Different research papers were studied and an estimate regarding the various parameters was concluded which showed that there are many factors which effect surface roughness and work piece such as cutting speed, feed, depth of cut, tool geometry, and tool material. Among them most favorable are cutting speed, feed and depth of cut.

3. EQUIPMENT SELECTION FOR EXPERIMENT AND SPECIFICATIONS

CNC Turning Lathe

Machine number in machine shop: 28

Manufacturer: L & L Taiwan

Model: TLA 34 x 3000

The experiment process was done using Computer Numerical Control (CNC) Lathe using Fanuc Controller 0iTC

3.1. Insert selection:The insert selected for turning operation is CNMG120404PF with tool holder WIDAX PDNNR 3232P-15

Fig. 1Turning of C-65 Forged Shaft

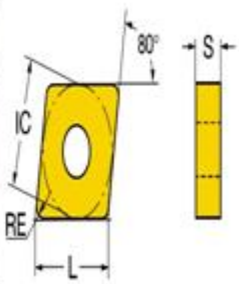


Fig.2 Insert in HolderFig.3 Insert Geometry

Chemical Composition

Grade	C	Si	Mn	S	P
C65	0.60-0.70	0.15-0.35	0.50-0.80	0.04	0.04

Mechanical Properties

Tensile Strength(Mpa)	Yield Strength (Mpa)	Elongation(%)	Hardness(HRB)
740	370	10	210

3.2. Parameters Selection:Experiments are performed to find the working levels of parameters. The parameters are chosen & classified as per the levels of input needed to perform the required statistical analysis.

The table below depicts the levels of observed parameters.

Table 1 Process Parameters

LEVEL	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	127	0.2	0.5
2	191	0.25	1
3	254	0.3	1.5

4. SURAFCE ROUGHNESS & MRR ANALYSIS

4.1. Measurement:Surface Roughness is measured using surface roughness tester Mitutoyo SJ201P for different values of spindle speed, feed and depth of cut using combinations suggested in L9 orthogonal array

- **For Surface Roughness**;

(a) Smaller the better characteristics

$$SN_i = -10 \log \left[\sum_{u=1}^{N_i} \frac{y_u^2}{N_i} \right]$$

Fig.4 Tester Calibration **Fig.5 Roughness Measurement**

- **For Material Removal Rate**;

(b) Larger the better characteristics

$$SN_i = -10 \log \left[\frac{1}{N_i} \sum_{u=1}^{N_i} \frac{1}{y_u^2} \right]$$

Where, MRR=V·f·d

5. EXPERIMENTATION PROCEDURE

- Prepare CNC lathe for machining of job.
- Mount the work piece on chuck using crane hoist & measure the diameter.
- Mount the tool holder with insert on V8 hydraulic tool post

- Set the turning program & required combination of parameters.
- Calibrate Surface Roughness tester using the sample piece
- After 1mm machining place tester on job and measure roughness
- Repeat above procedure for different combinations

6. Experiment Results & analysis

6.1.1.For Surface Roughness

The objective characteristic for surface roughness used was "smaller the better" as in above equation calculated using Minitab 17 is show in worksheet

Table 2 Response Table of S/N ratio for SRR

Level	Speed	Feed Rate	Depth of Cut
	(m/min)	(mm/rev)	(mm)
1	-9.06	-6.187	-8.503
2	-5.516	-7.18	-6.999
3	-7.855	-9.065	-6.93
Delta	3.544	2.879	1.572
Rank	1	2	3

Table 3 S/N ratio for SR

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6
	Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	SR	SNRA1	MEAN1
1	127	0.20	0.5	2.54	-8.0967	2.54
2	127	0.25	1.0	2.83	-9.0357	2.83
3	127	0.30	1.5	3.18	-10.0485	3.18
4	191	0.20	1.0	1.53	-3.6938	1.53
5	191	0.25	1.5	1.58	-3.9731	1.58
6	191	0.30	0.5	2.78	-8.8809	2.78
7	254	0.20	1.5	2.18	-6.7691	2.18
8	254	0.25	0.5	2.67	-8.5302	2.67
9	254	0.30	1.0	2.59	-8.2660	2.59

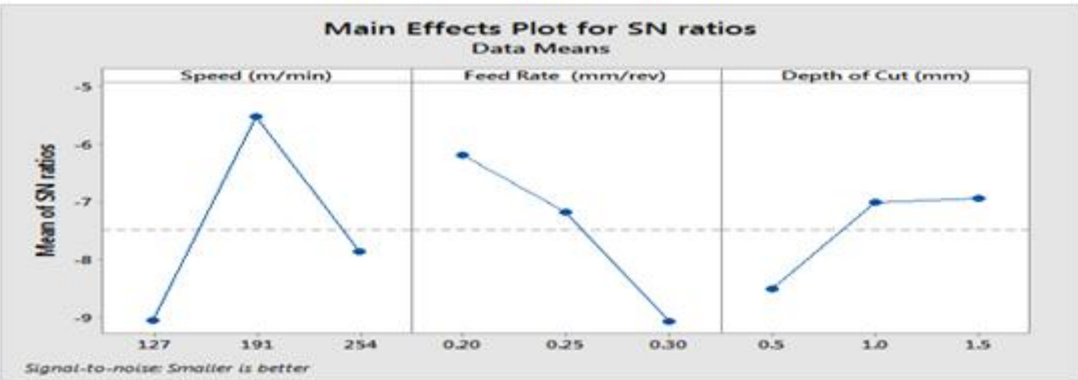


Fig.6 Main Effects Plots of SR

6.1.2. For Material Removal Rate

The values of material removal rate are transformed into s/n ratio for optimum combination of parameters. The objective characteristic for material removal rate used was "larger the better"

Table 4 S/N ratio for MRR

Worksheet 1 ***

↓	C1	C2	C3	C4	C5	C6
	Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	MRR	SNRA1	MEAN1
1	127	0.20	0.5	12700	82.0761	12700
2	127	0.25	1.0	31750	90.0349	31750
3	127	0.30	1.5	57150	95.1403	57150
4	191	0.20	1.0	38200	91.6413	38200
5	191	0.25	1.5	71620	97.1007	71620
6	191	0.30	0.5	28650	89.1425	28650
7	254	0.20	1.5	76200	97.6391	76200
8	254	0.25	0.5	31750	90.0349	31750
9	254	0.30	1.0	76200	97.6391	76200

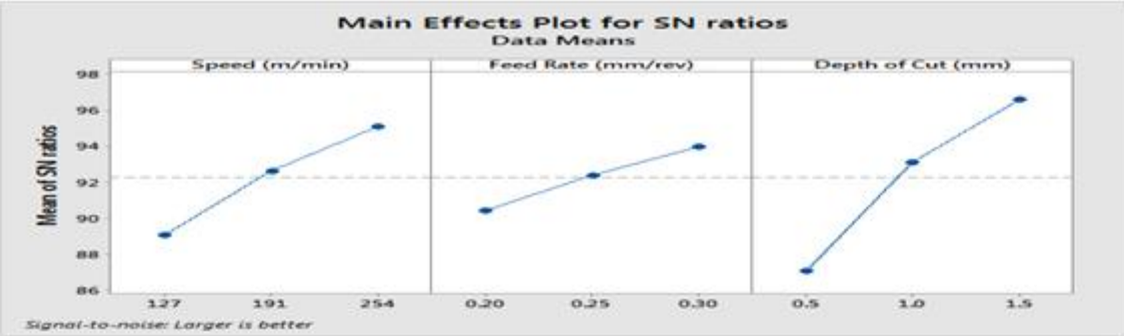


Fig.7 Main Effects Plots of MRR

Table 5 Response Table of S/N ratio for MRR

Level	Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	89.08	90.45	87.08
2	92.63	92.39	93.11
3	95.1	93.97	96.63
Delta	6.02	3.52	9.54
Rank	2	3	1

Table 6 GRC - GRG values

GRC		GRG
SR	MRR	AVERAGE
0.4464	0.3333	0.39
3875	0.4167	0.4
0.3333	0.625	0.48
1	0.4545	0.73
0.9259	0.8726	0.89
0.3968	0.4	0.39
0.5533	1	0.78
0.4167	0.4167	0.42
0.4347	1	0.72

Table 7 ANOVA of Grey Relation Grade

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution
Spindle Speed (rpm)	2	0.10869	0.054344	3.01	0.25	38%
Feed Rate (mm/rev)	2	0.01629	0.008144	0.45	0.689	6%
Depth of Cut (mm)	2	0.15722	0.078611	4.35	0.187	56%
Error	2	0.03616	0.018078			
Total	8	0.31836				

6.1.3. Calculation of Grey Relation Coefficient and Grey Relation

The equations below depict GRC and GRG calculation

$\zeta_i(k) = \frac{\Delta_{min} + \varsigma\Delta_{max}}{\Delta_{0i}(k) + \varsigma\Delta_{max}}$ where $\Delta_{0i}(k)$ is the deviation sequence of the reference sequence $x_0^*(k)$ and the comparability $x_i^*(k)$ sequence, namely

$\Delta_{0i}(k) = \|x_0^*(k) - x_i^*(k)\|$

$$\Delta_{max} = \max\max\|x_0^*(k) - x_i^*(k)\|$$

$$\Delta_{min} = \min\ \min\|x_0^*(k) - x_i^*(k)\|$$

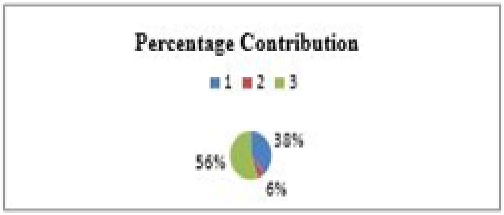
ς is distinguishing coeffcient, $\varsigma\epsilon[0,1]\varsigma =$ 0.5 is generally used

$$\Delta_{max} = \Delta_{04}(1) = \Delta_{09}(2) = 1.000$$

$$\Delta_{min} = \Delta_{03}(1) = \Delta_{01}(2) = 0.000$$

$$\text{GRG,} \quad \gamma_i = \frac{1}{n}\sum_{k=1}^{n}\zeta_i(k)$$

Pie Chart for Percentage Contribution



7. CONCLUSION

The following conclusions are to be drawn from experimental analysis:

- ✓ **Surface Roughness**

  Bestoptimized combinations are :

  Speed (A) at level 2 (191 m/min), feed (B) at level 1 (0.2 mm/rev), depth of cut (C) at level 3 (1.5 mm)

- ✓ **Material Removal Rate**

  Bestoptimized combinations are :

  Speed (A) at level 3 (254 m/min), feed (B) at level 3 (0.3 mm/rev), depth of cut (C) at level 3 (1.5 mm)

- ✓ **GRG** optimum parameters are Speed (A) at level 2 (191 m/min), feed (B) at level 1 (0.2 mm/rev), depth of cut (C) at level 3 (1.5 mm)

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