Process planning and cutting parameters optimization for CNC machining.

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Abstract— Computer Numerical Control (CNC) machine is an essential part of the industrial manufacturing process. It is important for fast production in the competitive world. The choice of process for CNC machining is important for the production of parts. In this study the process of the CNC machine in proper sequence for optimization of CNC machine parameters. The selection of process parameters as speed, feed and Depth for product manufacturing. The experiment has performed with the variables of speed, feed and depth of cut for the outcome of material removal rate (MRR) and surface roughness and find out the optimum levels of Parameters. The Experiment has performed according to the orthogonal array through grey relation analysis in Taguchi method. An optimum level of the experiment is identified by gey relation analysis. To validate the test, a confirmation test is performed. The experimental outcome is proved that the performed values increase efficiency through this fresh approach.

Index Terms— CNC turning, Parameters, Surface Roughness, Gray Relation analysis (GRA), Taguchi, Optimization.

1. Introduction

CNC machine is the advance industry machine which is used for high production and fulfil the requirement of market. So the parameters of machine is important for optimization of machine. Every industry want to maximum output with minimum input like fuel, electricity and man power. To achieve this goal it is important of optimize the parameters of machine.[1, 2]. In this paper Aluminium alloy AA6063 T6 is consider as a working material with parameters of feed, speed and depth of cut as input parameters and Material removal rate and surface roughness as outcome variables[3, 4]. This experiment is performed for minimum surface roughness and maximum material removal rate these variables is an important for product production.[5]. Material removal rate is an important factor for production, each industry wants to remove maximum material with minimum time[5]. It reduces the cost and production time and increases productivity. After material removal rate and surface roughness grey relation analysis is applied for rank and then applied taguchi method for optimization.

A.Saravanakumar is find out out the optimization of Aluminium Alloy AA6063 T6 using grey relation analysis in Taghichi method and conclude that feed is the most dominant factor than speed and depth of cut.[6, 7]. P. Jayaraman is find out out the optimization of Aluminium Alloy AA6063 T6 using grey relation analysis in Taghichi method and conclude that feed is the most dominant factor than speed and depth of cut.[8, 9].The experiment has been performed with multiple responses based on orthogonal L9 array with grey relation analysis (GRA) [10, 11].

2. Experimental Setup

2.1 Machining Process

Turning is the process in which material is removed in length of work piece. In the turning operation work piece hold in the chuck and its rotate with specific speed and tool is move in length of work piece according to the given speed and feed rate. [12]. Grey relation grade in Taguchi method is used for optimization process. A lot of research work is perform on optimization work.[6, 7].

2.2 Machine Tool

The machine tool which has been used for performing the experimental work is Speed Turn make CNC turning Centre Model ST – 400 G X750 (Siemens 808D) CNC system shown in fig. 1

(a) and machine specification has mentioned in Table 2. The factor which is considerable for the experiment is feed, Speed and DOC (Depth of cut). Experiment work has performed on three levels which is shown in Table 1[13, 14].

2.3 Experimental Plan

In this Research work, we use the L9 standard array in table 3. It is a suitable array for three levels and three parameters. It provides data with a change in a variable. Machining levels and Parameters are shown in Table.1.

Table. 1. Levels and Parameters

Machining parameters	Level 1	Level 2	Level 3
Feed (mm/rev)	0.06	0.08	0.1
Speed (RPM)	800	1000	1200
Depth of cut (mm)	0.7	1	1.3

Table2. CNC machine specification

Description	Measurement
Max. swing over bed	Ø 400 mm
Max. swing over carriage	Ø 240 mm
Max. Length of Work piece	1000 mm
Range of Spindle Speed	200-2000 rpm
Spindle Bore	Ø 60 mm

Table3. L9 standard array

Exp. No	A	B	C
	Speed	Feed	DOC
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Material removal rate (MRR) is calculated by

MRR=f*v*d (1)

v= (π*D*s)/60 (2)

Where

f = Feed in mm/rev

v = Velocity in mm/sec

d= Depth of cut in mm

D= Original diameter in mm

s=Speed in RPM

MRR=Material removal rate(mm3/sec)

SR= surface roughness in µm

2.4 Surface Roughness Tester

The values of surface roughness (SR) of experimental work piece were measured by using surface Roughness tester of Mitutoyo SJ-210 4mN shown in Fig. 1(b). SR testers get in contact with the surface of work piece for a few seconds to get Roughness value[8]. This process is repeated for performing many operations and get value. Aim is to be achieving minimum surface roughness. SR texture is a component of surface texture[13].

Fig.1.(a) CNC turning machine

Fig.1 (b) Surface roughness tester

2.5 Work piece material

Aluminium alloy AA6063 T6 has been used as a work material in this experiment because of their properties. It is a heat treatable alloy with high strength and good corrosion resistance. It also has an excellent machinability and surface finish. AA6063 T6 is used for screw, machine product, nuts, coupling, marine fitting, Hinge pin, Oil line fitting, and Valves.

Table.4. Chemical Composition of Aluminium Alloy AA6063 T6 by weight%

Chemical Elements	Per. (%)
Fe	0.34
Cu	0.09
Si	0.600
Cr	0.092
Mg	0.88
Mn	0.09
Ti	0.092
Zn	0.095
Al	97.721

3. Grey Relational Analysis (GRA) Method for Optimization

GRA is applied to convert multi-variables into a single variable and find out the optimum condition in which MRR in mm3/sec is maximum and Surface roughness in µm is minimum[15]. The following steps are used for Grey relation grade (GRG)[8, 9].

Step 1: Grey relational generation
In this step, we find out the Normalization of the experiment performed.

Table.5. Experimental values for L9 Array

Exp.No	Speed (rpm)	Feed (mm/rev)	DOC (mm)	SR (µm)	MRR (mm3/sec)
1	800	0.06	0.7	0.616	35.69552
2	800	0.08	1	0.615	67.99147
3	800	0.1	1.3	1.617	110.48613
4	1000	0.06	1	1.118	63.74200
5	1000	0.08	1.3	1.822	110.48613
6	1000	0.1	0.7	0.82	74.36567
7	1200	0.06	1.3	0.665	99.43752
8	1200	0.08	0.7	7.5	71.39104
9	1200	0.1	1	4.6	127.48400

$$x_i^*(k) = \frac{x_i^k(k) - \min(x_i^0(k))}{\max(x_i^0(k)) - \min(x_i^0(k))} \quad (3)$$

In the present work, the surface Roughness has to be minimized and the normalization of experimental data can be calculated as follows.

$$x_i^*(k) = \frac{\max(x_i^0(k)) - x_i^k(k)}{\max(x_i^0(k)) - \min(x_i^0(k))} \quad (4)$$

Step 2 Calculated deviation sequence is for each exp. and shown in table 6.

Step 3 Calculated Grey Relation Coefficient for surface Roughness and MRR.

$$\zeta_i(K) = \frac{\Delta\min + \mu * \Delta\max}{\Delta_{0i}(k) + \mu * \Delta\max} \quad (5)$$

Here, $\Delta_{0i}(y)$ is deviation sequence

$$\Delta_{0i}(y) = |x_0^*(y) - x_i^*(y)| \quad (6)$$

Table.6. Grey relational normalization and Δ_{0i} is deviation sequence calculated with reference sequence 1

Exp.No	Normalized data		Deviation sequence Δ0i	
	MRR (mm3/sec)	SR(µm)	MRR (mm3/sec)	SR(µm)
1	0.00000	0.99985	1.00000	0.00015
2	0.35185	1.00000	0.64815	0.00000
3	0.81481	0.85447	0.18519	0.14553
4	0.30556	0.92694	0.69444	0.07306
5	0.81481	0.82469	0.18519	0.17531
6	0.42130	0.97023	0.57870	0.02977
7	0.69444	0.99274	0.30556	0.00726
8	0.38889	0.00000	0.61111	1.00000
9	1.00000	0.42121	0.00000	0.57879

Table.7. Gray Relation coefficient for each experimental value and Overall GRG.

Exp.No	Grey relational coefficient		Gray relational grade
	MRR (mm3/sec)	SR(µm)	
1	0.33333	0.99971	0.66652
2	0.43548	1.00000	0.71774
3	0.72973	0.77455	0.75214
4	0.41860	0.87251	0.64556
5	0.72973	0.74040	0.73507
6	0.46352	0.94380	0.70366
7	0.62069	0.98568	0.80319
8	0.45000	0.33333	0.39167
9	1.00000	0.46348	0.73174

minimum value for $\Delta_{0i}(y)$ is Δ min , and maximum for Δ_{0i} is Δ max [21].

$$\Delta_{0i}(y) = \Delta min = min|x_0^*(y) - x_i^*(y)| \quad (7)$$

$$\Delta_{0i}(y) = \Delta max = max|x_0^*(y) - x_i^*(y)| \quad (8)$$

0.5 is the value of (μ) i.e. identification coefficient its range is $0 \le \mu \le 1$

$\Delta max = 1$ (MRR)

$\Delta min = 0$ (Surface Roughness)

Table 7 shows the Grey relational coefficient of experimental values.

Step 4 Calculate Overall GRG. Surface Roughness & MRR are two factors, Table 7 show GRG for machining parameters[16].

Table 7 The maximum value of GRG is shown in experiment No. 9

Step 5 Calculate the mean of GRG.

The mean of GRG is the average sum of Grey Relational coefficient.

$$\gamma(x_0^*, x_i^*) = \gamma_i = \frac{1}{n}\sum_{k=1}^{n} \zeta_i(k) \quad (9)$$

Here, n is the number of process parameters.

Step 6: Grey relational ordering

Greatest grey relational grade gives an order 1. Eq. 7 is used to calculate Grey relational grades. From table 7, we find out that exp. 7 has the greatest Gray Relational Grade. The larger value in the S/N curve is considered as an optimum parameter. So the optimum turning parameters has s1f3d3[8, 17].

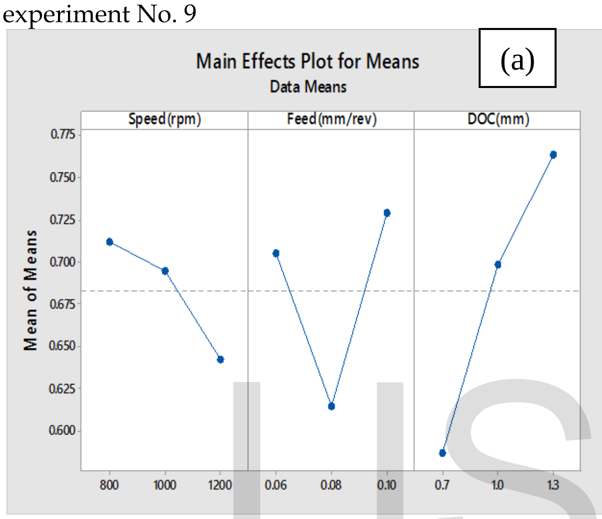

Fig.3. (a) Main effect plots for Mean for Grey relation grade

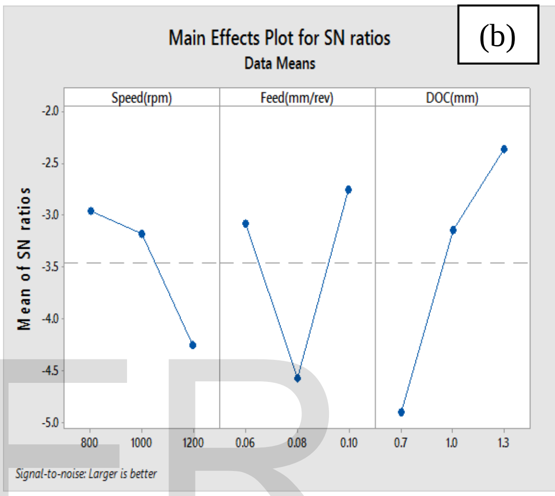

Fig.3. (b) Main effect plots for S/N ratio for Grey relation grade

Table.8. Means for GRG Response Table

Level	Speed	Feed	DOC
1	0.7121	0.7051	0.5873
2	0.6948	0.6148	0.6983
3	0.6422	0.7292	0.7635
Delta	0.0699	0.1144	0.1762
Rank	3	2	1

Table.9. S/N Ratios Response Table Response Table for Means

Larger is better

Level	Speed	Feed	DOC
1	-2.959	-3.076	-4.906
2	-3.176	-4.565	-3.132
3	-4.253	-2.747	-2.350
Delta	1.293	1.819	2.556
Rank	3	2	1

4. Result and Discussions

Mean of GRG shown in table 8. It represents the significant levels of parameters. Significant level is the difference between maximum and minimum values of process parameters. Greater significant is the greatest difference. From table.8 it's clear that Feed has more contribution to optimization followed by depth of cut and speed. It gives a maximum MRR and minimum surface Roughness. Fig.3 (a) show the mean of GRG and Fig. 3 (b) shows the Main effect plots of S/N ration. Fig.3 (a) shown that-

- With an increase speed, GRG decrease up to level 3.
- With an increase of feed, GRG decrease up to level 2, then increase up to level 3.
- With an increase of depth of cut, GRG increase up to level 3.

Table.10. Results

Experiment	Parameters	SR	MRR
Initial Prediction	s3f1d3	0.665	99.43752
Experimental	s1f3d2	0.945	123.88357

5. Conclusions

The speed, feed and depth of cut are measured under the different cutting condition for find out the optimum combination In this present work we found out the optimum combination of process parameters naming Speed, Feed and Depth of cut for maximum MRR and Minimum Surface Roughness through GRG, it is the best method to find out the optimum value with least time. Following experiment results are concluding.

- Optimum process parameters are s1f3d3 i.e. speed 800 RPM, Feed 0.1 mm/rev and DOC 1.3 mm.
- Optimum Surface Roughness is 0.945 µm.
- Optimum MRR is 123.88357 mm3/sec.
- For the optimization, Depth of cut has the main factor it has First Rank.
- Feed has the second Rank.
- Speed has a third Rank.

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