Optimization of Process Parameters of SS 202 on Vertical Milling Machine using Grey Relational Analysis

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Abstract— As the advancement in the technology some new material are comes in a trend which offers high strength, hardness and resistance to heat. Face milling is a very common method for metal cutting and the finishing of machined parts. The input machining parameters being consider in this research are spindle speed, tool feed and depth of cut. The stainless steel 202 used as work piece. The tool used for the face milling operation is High Speed Steel face milling cutter. The Taguchi's L16 orthogonal array has been used to design the combinations of parameters for the experiments. The surface roughness of SS 202 has been measured after face milling operations and also material removal rate has been measured after the operations. The machining experiments are performed on Computer Numerical Control Vertical Milling Machine (640). Grey Relational analysis is used for finding the optimal values from the all experimental values. The optimum levels of input parameters have been found by Grey analysis are spindle speed 2000 rpm, 400 mm/rev tool feed and 0.2 mm depth of cut for maximum material removal rate and minimum surface roughness.

Key words: Process Parameters of SS 202, Grey Relational Analysis

I. Literature Review

Dereli et al. (2001) introduced 'system software' developed to optimize the cutting parameters for prismatic parts. The system is mainly based on a powerful artificial intelligence (AI) tool, called genetic algorithms (GAs). It is implemented using C programming language and on a PC. It can be used as standalone system or as the integrated module of a process planning system called OPPS-PRI (Optimized Process Planning System for prismatic parts) that was also developed for prismatic parts and implemented on a vertical machining centre (VMC).

Hsiao et al. (2008) investigated the optimal parameters of plasma arc welding (PAW) by the Taguchi method with Grey relational analysis. The Grey relational grade is used to find optimal PAW parameters with multiple response performance characteristics. The welding parameters (welding current, welding speed, plasma gas flow rate, and torch stand-off) are optimized with consideration of the multiple response performance characteristics (the penetration of root, the weld groove width, and the weld pool undercut).

Joshi et al. (2012) investigated effects of various parameters of end milling process like spindle speed, depth of cut, feed rate have been investigated to reveal their Impact on Material Removal Rate using Taguchi Methodology. Experimental plan is performed by a Standard Orthogonal Array. The results of analysis of variance (ANOVA) indicate that the proposed mathematical model can be adequately describing the performance within the limit of factors being studied. The optimal set of process parameters has also been predicted to maximize the MRR.

Manimaran and Kumar (2013) investigated grinding process for AISI 316 stainless steel by the Taguchi and grey relational analysis under the three environments of dry, conventional, and cryogenic cooling. The performance characteristics considered are, the material removal rate (MRR), surface roughness (Ra), and grinding force (Ft). Experiments were conducted with Al_2O_3 (Aluminum Oxide) and Sol-Gel (SG) grinding wheels under different cutting conditions. An orthogonal array L18 is used for the experimental design.

II. Stainless Steel 202(SS202)

Grade 202 stainless steel is a type of Cr-Ni-Mn stainless. The toughness of grade 202 at low temperatures is excellent. It is one of the most widely used precipitation hardening grades, and possesses good corrosion resistance, toughness, high harness, and strength. The chemical composition of SS 202 is given in table 1 below.

Contituent	% Composition
C	0.1291
Cr	16.40
Mn	5.479
Si	0.4900
P	0.04129
S	0.02157
Cu	0.2943
V	0.0393
Ni	3.59
Mo	0.2500

Table 1: Chemical Composition of SS 202

The mechanical, physical and electrical properties of SS 202 as shown in table 2

Tensile Strength (MPa)	515
Yield Strength (MPa)	275
Hardness(HB)	230
Elastic Modulus(GPa)	207

Table 2: Mechanical, Physical and Electrical properties

III. Design of Experiment and Data Collection

Run	Column 1	Column 2	Column 3
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1

7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

Table 3: L16 Orthogonal array

Run	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	Surface Roughness (µs)		Mean SR	S/N ratio
				SR1	SR2		
1	1000	100	0.4	0.518	0.530	0.5240	5.6128
2	1000	200	0.3	0.257	0.235	0.2460	12.1726
3	1000	300	0.2	0.439	0.442	0.4405	7.1210
4	1000	400	0.1	0.628	0.608	0.6180	4.1791
5	1500	100	0.3	0.191	0.198	0.1945	14.2202
6	1500	200	0.4	0.245	0.230	0.2375	12.4824
7	1500	300	0.1	0.270	0.247	0.2585	11.7422
8	1500	400	0.2	0.369	0.357	0.3630	8.8007
9	2000	100	0.2	1.798	1.743	1.7705	-4.9630
10	2000	200	0.1	0.674	0.689	0.6815	3.3302
11	2000	300	0.4	0.439	0.421	0.4300	7.3287
12	2000	400	0.3	0.247	0.219	0.2330	12.6372
13	2500	100	0.1	0.182	0.164	0.1730	15.2273
14	2500	200	0.2	0.161	0.179	0.1700	15.3789
15	2500	300	0.3	0.661	0.664	0.6625	3.5763
16	2500	400	0.4	0.801	0.812	0.8065	1.8677

Table 4: L16 Orthogonal array of surface roughness

Run	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	MRR (g/sec.)		Mean	S/N ratio
				MRR1	MRR2		
1	1000	100	0.4	0.350	0.298	0.3240	-9.8731
2	1000	200	0.3	0.560	0.568	0.5640	-4.9751
3	1000	300	0.2	0.528	0.580	0.5540	-5.1585
4	1000	400	0.1	0.225	0.258	0.2415	-12.4025
5	1500	100	0.3	0.099	0.128	0.1135	-19.1133
6	1500	200	0.4	0.342	0.286	0.3140	-10.1651
7	1500	300	0.1	0.064	0.095	0.0795	-22.4913
8	1500	400	0.2	0.442	0.470	0.4560	-6.8330
9	2000	100	0.2	0.647	0.611	0.6290	-4.0377
10	2000	200	0.1	0.152	0.175	0.1635	-15.7942
11	2000	300	0.4	0.533	0.576	0.5545	-5.1416
12	2000	400	0.3	0.540	0.578	0.5590	-5.0668
13	2500	100	0.1	0.173	0.168	0.1705	-15.3683
14	2500	200	0.2	0.280	0.341	0.3105	-10.2847
15	2500	300	0.3	0.089	0.113	0.1010	-20.0979
16	2500	400	0.4	0.280	0.257	0.2685	-11.4450

Table 5: L16 Orthogonal array of material removal rate

IV. Result and Analysis

To study the effect of output responses on the surface finish and material removal rate using GRA, the data analyzed to better condition of the work. It is necessary which parameter gives better surface finish and higher material removal rate.

Run	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	Normalized S/N ratios	
				MRR	SR
1	1000	100	0.4	0.6838	0.4800
2	1000	200	0.3	0.9492	0.1576
3	1000	300	0.2	0.9392	0.4059
4	1000	400	0.1	0.5467	0.5505
5	1500	100	0.3	0.1830	0.0569
6	1500	200	0.4	0.6679	0.1423
7	1500	300	0.1	0.0000	0.1787
8	1500	400	0.2	0.8485	0.3233
9	2000	100	0.2	1.0000	1.0000

10	2000	200	0.1	0.3629	0.5923
11	2000	300	0.4	0.9401	0.3957
12	2000	400	0.3	0.9442	0.1347
13	2500	100	0.1	0.3859	0.0074
14	2500	200	0.2	0.6614	0.0000
15	2500	300	0.3	0.1296	0.5802
16	2500	400	0.4	0.5985	0.6642

Table 6: Normalized signal to noise ratios

The normalized S/N ratio for SR and MRR in table 6 is calculated with the help of relation

$$\frac{Yij - \min(Yij, i = 1,2,3, \dots, n)}{\max(Yij, i = 1,2,3, \dots, n) - \min(Yij, i = 1,2,3, \dots, n)}$$

(for maximum MRR)

$$\frac{\max(Yij, i = 1,2,3, \dots, n) - Yij}{\max(Yij, i = 1,2,3, \dots, n) - \min(Yij, i = 1,2,3, \dots, n)}$$

(for minimum SR)

After calculating the normalized S/N ratio, grey relational coefficient is calculated to express relation between ideal and actual normalized result. Before that the deviation sequence were found. The Deviation sequences for SR and MRR is shown in table 7.

Run	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	Deviation sequence	
				MRR	SR
1	1000	100	0.4	0.3162	0.5200
2	1000	200	0.3	0.0502	0.8424
3	1000	300	0.2	0.0608	0.5941
4	1000	400	0.1	0.4533	0.4495
5	1500	100	0.3	0.8170	0.9431
6	1500	200	0.4	0.3321	0.8577
7	1500	300	0.1	1	0.8213
8	1500	400	0.2	0.1515	0.6767
9	2000	100	0.2	0	0
10	2000	200	0.1	0.6371	0.4077
11	2000	300	0.4	0.0599	0.6043
12	2000	400	0.3	0.0558	0.8653
13	2500	100	0.1	0.6141	0.9926
14	2500	200	0.2	0.3386	1
15	2500	300	0.3	0.8704	0.4198
16	2500	400	0.4	0.4015	0.3358

Table 7: Deviation sequence

After calculating deviation sequence, grey relation coefficient in table 8 is calculated with the help of relation

$$x(k) = \frac{\Delta \min + \zeta \Delta max}{\Delta o + \zeta \Delta max}$$

Here ζ is distinguishing or identified coefficient and ζ= 0.5 is generally used.

Run	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	grey relational cofficient	
				MRR	SR
1	1000	100	0.4	0.6125	0.4901
2	1000	200	0.3	0.9087	0.3724
3	1000	300	0.2	0.8915	0.4569
4	1000	400	0.1	0.5244	0.5265
5	1500	100	0.3	0.3796	0.3464
6	1500	200	0.4	0.6008	0.3682
7	1500	300	0.1	0.3333	0.3784
8	1500	400	0.2	0.7674	0.4249
9	2000	100	0.2	1	1
10	2000	200	0.1	0.4397	0.5508
11	2000	300	0.4	0.8930	0.4527
12	2000	400	0.3	0.8996	0.3662
13	2500	100	0.1	0.4487	0.3349
14	2500	200	0.2	0.5962	0.3333
15	2500	300	0.3	0.3648	0.5435
16	2500	400	0.4	0.5546	0.5982

Table 8: Grey Relational Coefficient

After this grey relation grade is calculating by averaging the grey relational coefficient corresponding to each performance characteristic as shown in table 9.

Run	Spindle speed(rpm)	Tool Feed(mm/rev)	Depth of cut(mm)	Grey relational grade	Rank
1	1000	100	0.4	0.5513	8
2	1000	200	0.3	0.6405	4
3	1000	300	0.2	0.6742	2
4	1000	400	0.1	0.5254	9
5	1500	100	0.3	0.3630	15
6	1500	200	0.4	0.4845	11
7	1500	300	0.1	0.3558	16
8	1500	400	0.2	0.5961	6
9	2000	100	0.2	1	1
10	2000	200	0.1	0.4952	10
11	2000	300	0.4	0.6728	3
12	2000	400	0.3	0.6329	5
13	2500	100	0.1	0.3918	14
14	2500	200	0.2	0.4647	12
15	2500	300	0.3	0.4541	13
16	2500	400	0.4	0.5764	7

Table 9: Grey Relational Grade

V. Determination of the Optimum Factor Level Combination

Figure 6.1 shows the grey relational grade for maximum MRR and minimum SR. Table 6.4 shows the experimental result for the grey relational grade. The higher value of grey relational grade represents the stronger relational degree between the reference sequence and given sequence. The higher value of grey relational grade means that the corresponding cutting parameter is closer to optimal. From table 6.4 shows spindle speed of level 3, tool feed of level 1 and depth of cut level 3 will closer to optimal solution.

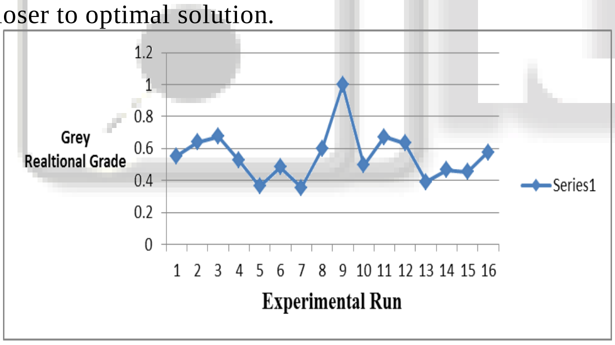

Fig. 6.1: Grey relational grade for maximum MRR and minimum SR

The larger the grey relational grade better is the multiple performance characteristics. However, the relative importance among the machining parameters for the multiple performance characteristics still need to be known, so with the help of table 6.5 and figure 6.2, figure 6.3 and figure 6.4, the optimal parameter was determined as A3(spindle speed, 2000 rpm), B4(tool feed, 400 mm/rev) and C3(depth of cut, 0.2).

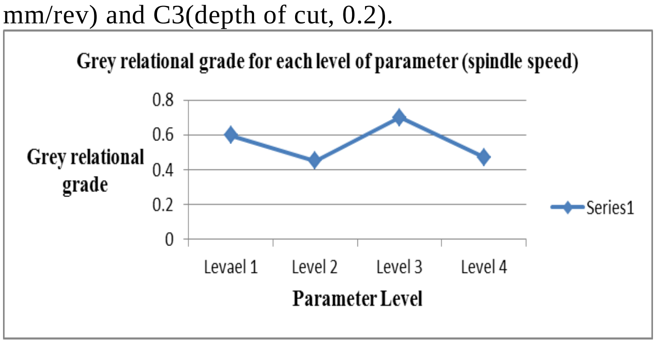

Fig. 6.2: Grey relational grade with respect of spindle speed

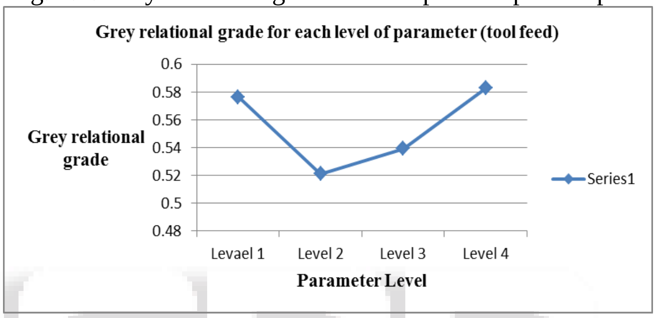

Fig. 6.3: Grey relational grade with respect of tool feed

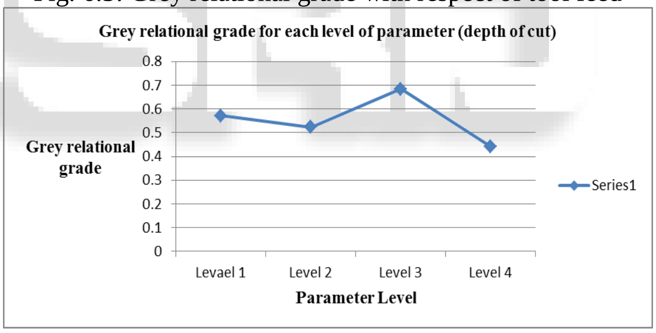

Fig. 6.4: Grey relational grade with respect of depth of cut

Parameter	Level 1	Level 2	Level 3	Level 4	Max-Min	rank
Spindle speed	0.5978	0.4498	0.7002*	0.4717	0.2504	1
Tool feed	0.5765	0.5212	0.5392	0.5827*	0.0615	3
Depth of cut	0.5712	0.5226	0.6837*	0.4420	0.2417	2

Table 6.5: Main effect of factors on grey relational grade

VI. Predicting Optimum Performance at These Levels

Using the optimal parameters, the Optimum output Characteristics (Surface roughness, Material removal rate) at A3B4C3 are predicted by

– Predicted mean = Average of A3 + Average of B4 + Average of C3 - 2* Mean of response
– Predicted mean MRR= 0.4765 + 0.3812 + 0.4873 – 2* 0.3376 = 0.6698 g/sec.

– Predicted mean SR= 0.7787 + 0.5051 + 0.6860 – 2*0.4880 = 0.9938 µm.

VII. CONCLUSION

1) Taguchi's robust design method is suitable to analyze the metal cutting problem as described in the present work.
2) Grey relational analysis was applied in this work for multi response characteristics such as MRR and SR.
3) In face milling, on third level of spindle speed grey relational coefficient is maximum within specified test range.
4) In face milling, on forth level of tool feed grey relational coefficient is maximum within specified test range.
5) In face milling on third level of depth of cut grey relational coefficient is maximum within specified test range.
6) The optimal parameters combination was determined as A3B4C3 i.e. spindle speed at 2000 rpm, tool feed at 400 mm/rev and depth of cut at 0.2 mm.
7) From this investigation it has been analyzed that spindle speed is most effectible factor which affect the output responses.

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