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Multi-Objective Optimization (Surface Roughness & Material Removal Rate) of Aisi 202 Grade Stainless Steel in Cnc Turning Using Extended Taguchi Method And Grey Analysis

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ABSTRACT
The present study applied Taguchi method through a case study in straight turning of AISI 202 stainless steel bar on CNC Machine (Mfd by ACE DESIGNERS) using Titanium Carbide tool for the optimization of Material removal rate, Surface Roughness and tool wear process parameter.The study aimed at evaluating the best process environment which could simultaneously satisfy requirements of both quality as well as productivity with special emphasis on maximizing material removal rate and minimizing surface roughness and tool flank wear at various combination of cutting speed, feed, depth of cut. The predicted optimal setting ensured maximum MRR and minimum surface roughness and tool wear. Since optimum material removal rate is desired, so higher the better criteria of Taguchi signal to noise ratio is used for MRR –
$SN_s = -10 \log(Sy^2/n)$
For surface roughness and tool wear –

$$SN_L = -10 \log(S(1/y^2)/n)$$

The results have been verified with the help of S/N Ratios calculation and various graphs have been plotted to show the below mentioned observations.
a) MRR first increases with increase in cutting speed and then decreases.
b) With the increase in feed, MRR increases.
c) With the increase in depth of cut, MRR first increases and then decreases.
d) With the increase in cutting speed, Surface Roughness first decreases and then increases.
e) With the increase in feed, Surface Roughness increases.
f) With the increase in depth of cut, Surface Roughness first increases and then decreases.
Keywords: *CNC turning machine, Grey relational analysis, Material removal rate, Surface roughness.*

I. INTRODUCTION

AISI 202 stainless steel belonging to the low nickel and high manganese stainless steel, the nickel content is generally below 4%, 8% of the manganese content is a section of nickel stainless steel. AISI 202 stainless steel is 200 series stainless steel. AISI 202 stainless steel is a section with good mechanical properties of corrosion resistance, AISI 202 stainless steel high temperature strength than steel, 18-8, at 800 °C, the following has good oxidation resistance, and maintain a high intensity, can replace SUS302 steel. AISI 202 stainless steel is widely used in architectural decoration, municipal engineering, guardrail, hotel facilities, shopping mall, vitreous armrest, public facilities etc. The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine. M.Kladhar [1] from the analysis, observed that the feed is the most significant factor that influences the surface roughness followed by nose radius. he attempted to generate prediction models for surface roughness. The predicted values are confirmed by using validation experiments.[1]

It was reported that austenitic stainless steels come under the category of difficult to machine materials [1]. Little work has been reported on the determination of optimum machining parameters when machining austenitic stainless steels. Lin [8] investigated surface roughness variations of different grades of austenitic stainless steel under different cutting conditions in high speed fine turning. Ranganathan and Senthilvalen [9] developed a mathematical model for process parameters on hard turning of AISI 316 stainless steel. Surface roughness and tool wear was predicted by Regression analysis and ANOVA theory. Anthony xavior and Adithan [10] determined the influence of different cutting fluids on wear and surface roughness in turning of AISI304 austenitic stainless steel. Ibrahim Ciftci [10] conducted the experiments to Machine AISI 304 and AISI 316 austenitic stainless steels using CVD multi-layer coated cemented carbide tools. The results showed that cutting speed significantly affected the machined surface roughness values. The goal of the modern industry is to manufacture high quality products in a short time. Computer Numerical Control (CNC) machines are capable of achieving high accuracy with very low processing time [1,2]. During machining, surface quality is one of the most specified customer requirements.. In the present study the multi-objective optimization of surface roughness and material removal rate of AISI 202 has been done using Taguchi method and Grey analysis [6].

II. DESIGN OF EXPERIMENT

Experiments have been carried out using Taguchi's L_9 Orthogonal Array (OA) experimental design which consists of 9 combinations of spindle speed, longitudinal feed rate and depth of cut. According to the design catalogue [Peace, G., S., (1993)] prepared by Taguchi, L_9 Orthogonal Array design of experiment has been found suitable in the present work.

Table 1: Process variables and their limits

Values In Coded Form	Cutting Speed M/Min	Feed (F) Mm/Rev	Depth Of Cut (D) Mm
-1	115	0.07	0.6
0	130	0.14	1.2
1	145	0.21	1.8

Table 2: Taguchi's L_9 Orthogonal Array for MRR S/N Ratio

Sample No	Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	MRR (Gm/Sec)	S/N Ratio
1	115	.07	.6	0.94	-0.54
2	115	.14	1.2	2.91	9.24
3	115	.21	1.8	2.75	8.76
4	130	.07	1.2	1.31	2.34
5	130	.14	1.8	2.65	8.48
6	130	.21	.6	5.28	14.45
7	145	.07	1.8	2.38	7.53
8	145	.14	.6	1.25	1.93
9	145	.21	1.2	3.67	11.27

Table 3: S/N Ratio Calculation for Surface Roughness

Sample No	Cutting Speed (M/Min)	Feed (Mm/Rev)	Depth Of Cut (Mm)	MRR (Gm/Sec)	Surface Roughness Mean (Ra)	S/N Ratio
1	115	.07	.6	0.94	2.11	6.48
2	115	.14	1.2	2.91	2.61	8.33
3	115	.21	1.8	2.75	2.353	7.43
4	130	.07	1.2	1.31	1.89	5.52
5	130	.14	1.8	2.65	2.3	7.20
6	130	.21	.6	5.28	2.29	7.19
7	145	.07	1.8	2.38	1.923	5.66
8	145	.14	.6	1.25	2	6.02
9	145	.21	1.2	3.67	2.673	8.53

III. EXPERIMENTAL SET UP

Nine nos samples of Material AISI 202 were taken for machining and their weight before machining and after machining were precisely recorded and time taken using a calibrated watch and following observations were recorded.

S.S. bars of diameter 31mm and length 41mm required for conducting the experiment have been prepared first. Nine no of samples of same material and same dimensions have been made. After that the weight of each sample has been measured accurately with the help of digital balance meter. Then using different levels of the process parameters nine specimens have been turned on CNC lathe machine accordingly. Machining time for each sample has been calculated accordingly. The surface roughness of the work pieces have been measured by stylus type surface roughness tester Mitutoyo SJ-211.


- **WORK PIECE MATERIAL**:
  Stainless Steel AISI 202.Dimension for material is Ø31 X 41 mm.

- **CHEMICAL COMPOSITION**

AISI	C	Mn	P	S	Si	Cr	Ni
202	<=0.15	7.50-10.0	<=0.06	<=0.03	<=0.75	17.0-19.0	4.0-6.0

- **SELECTION OF CUTTING TOOL:**
  The cutting tool selected for present work is Titanium carbide.

IV. GREY RELATIONAL ANALYSIS

Data Normalization It is the first step in the grey relational analysis.

$$x_i(k) = \frac{y_i(k) - \min y_i(k)}{\max y_i(k) - \min y_i(k)} \quad \text{; (higher-the-better)} \qquad (1)$$

$$x_i(k) = \frac{\max y_i(k) - y_i(k)}{\max y_i(k) - \min y_i(k)} \quad \text{; (lower-the better)} \qquad (2)$$

Where xi (k) is the sequence of the surface roughness and material removal rate after data normalization, max yi(k) and min yi(k) are the largest value and smallest value of original sequence of surface roughness and MRR respectively.

V. GREY RELATIONAL COEFFICIENT CALCULATION

After normalization of original sequence, Grey relational coefficient is calculated

$$\xi_i(k) = \frac{\Delta_{\min} + \xi \cdot \Delta_{\max}}{\Delta_{0i}(k) + \xi \cdot \Delta_{\max}}$$

VI. GREY RELATIONAL GRADE

The grey relational grade can be calculated by using the below mentioned formula—

$$\alpha_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k)$$

Table-4: OPTIMUM PROCESS PARAMETERS FOR MULTI OBJECTIVE OPTIMIZATION USING GREY ANALYSIS

S.NO	GRGC		RSDC		GRCC	
	MRR	Ra	MRR	Ra	MRR	Ra
X0	1.000	1.000	1.000	1.000	1.000	1.000
1	0.000	0.719	1.000	0.281	0.333	0.640
2	0.450	0.080	0.550	0.920	0.476	0.352
3	0.416	0.408	0.584	0.592	0.461	0.457
4	0.084	1.000	0.916	0.000	0.353	1.000
5	0.396	0.476	0.604	0.524	0.452	0.488
6	1.000	0.489	0.000	0.511	1.000	0.494
7	0.331	0.957	0.669	0.043	0.427	0.920
8	0.070	0.859	0.930	0.141	0.349	0.780
9	0.627	0.000	0.373	1.000	0.572	0.333

GRGC - Grey Relational Generation calculation
RSDC - Reference Sequence Definition calculation
GRCC - Grey Relational Coefficient Calculation

Table -5:

S.No	Grey Relational Grade (GRG)	Rank
1	0.486	5
2	0.414	9
3	0.459	7
4	0.676	2
5	0.470	6
6	0.747	1
7	0.673	3
8	0.564	4
9	0.452	8

Higher GRG means that the corresponding parameter combination is the optimal.

VII. RESULT AND CONCLUSION

The optimum values of Process variables for MRR are-

Cutting speed = 130 m/min
Feed = .21mm/rev
Depth of cut = .6 mm

The results have been verified with the help of S/N Ratios calculation and various graphs have been plotted to show the below mentioned observations.

a) MRR first increases with increase in cutting speed and then decreases.
b) With the increase in feed, MRR increases.
c) With the increase in depth of cut MRR first increases and then decreases.

MRR VS CUTTING SPEED

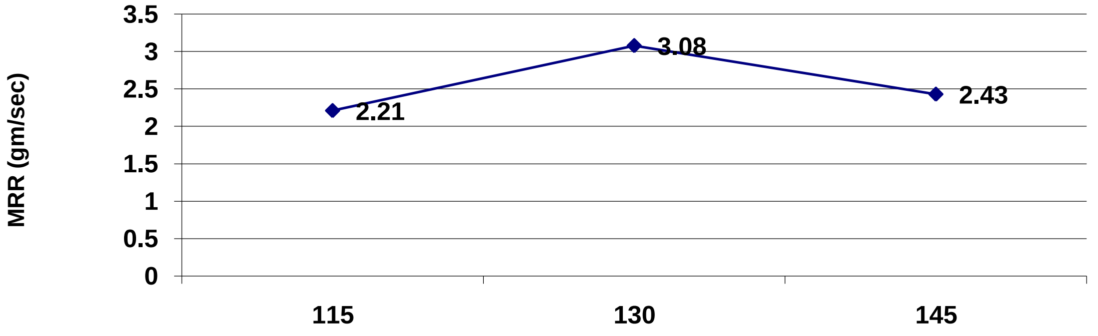


Fig:1

MRR VS DEPTH OF CUT

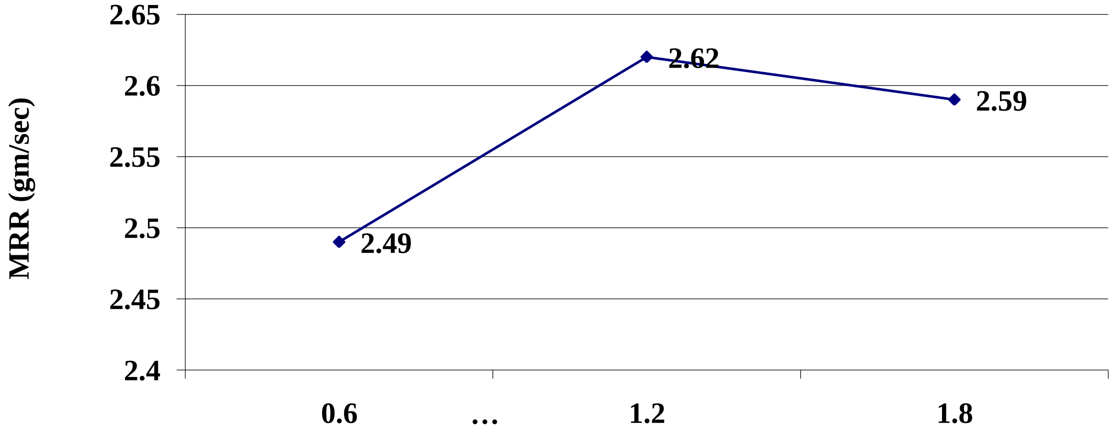


Fig 2

PLOT OF MRR VS FEED

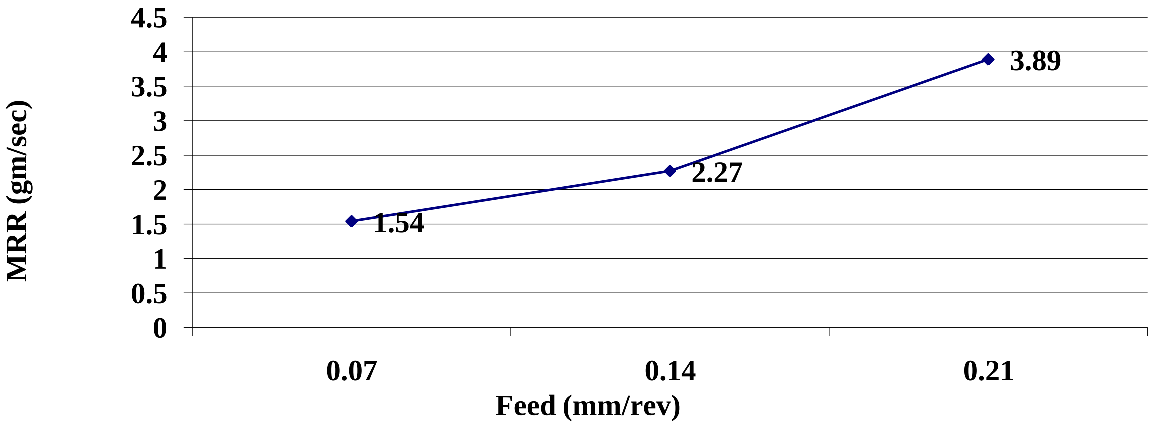


Fig 3

The optimum value of Process variables for Surface Roughness are---

Cutting speed = 130 m/min
Feed = .07 mm/rev
Depth of cut = 1.2 mm

Conclusions for Surface Roughness

a) With the increase in cutting speed Surface Roughness first decreases and then increases.
b) With the increase in feed, Surface Roughness increases.

c) With the increase in depth of cut Surface Roughness first increases and then decreases.

Surface Roughness Vs Cutting Speed

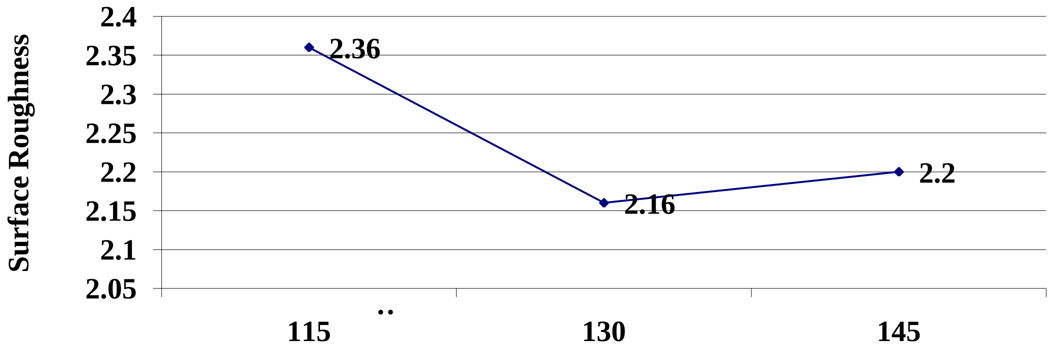
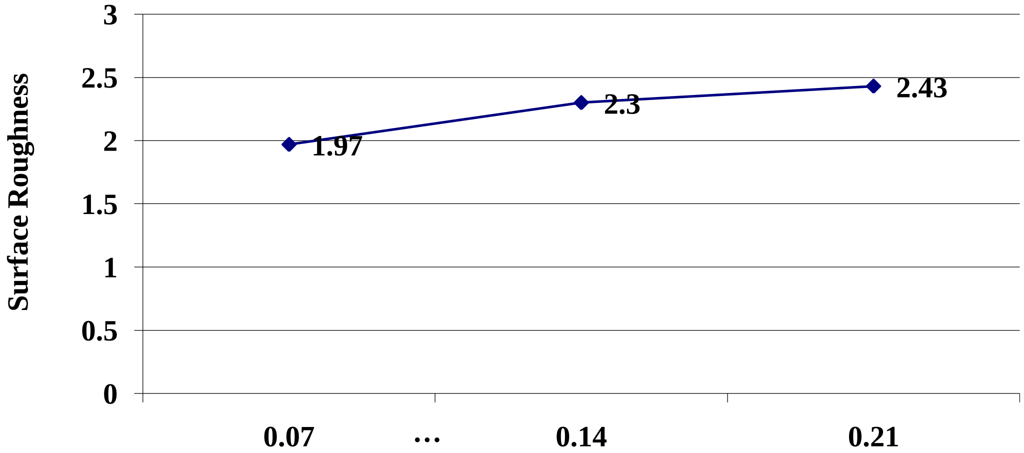


Fig 4.7

Plot of Surface Roughness Vs Feed



Surface Roughness Vs Depth of Cut

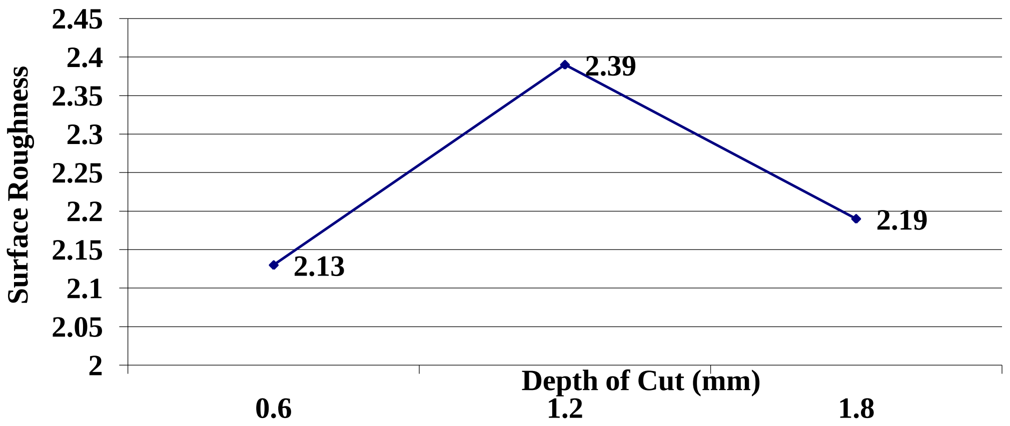


Fig-4.9

Grey analysis shows that optimum value of process variable for multi-objective optimization of MRR and Surface Roughness are-

Higher GRG means that the corresponding parameter combination is the optimal.Grey analysis shows that optimum value of process variable for multi-objective optimization of MRR and Surface Roughness :

Cutting Speed -- 130 m/sec
Feed -- .21mm/rev
Depth of Cut -- .6 mm

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