OPTIMIZATION OF MACHINING PARAMETERS FOR CNC LATHE MACHINE

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Abstract : Quality and productivity play significant role in today's manufacturing market. In machining operations, achieving desired surface quality features of the machined product, is really a challenging job on CNC machine. Because, these quality features are highly correlated and are expected to be influenced directly or indirectly by the direct effect of process parameters. There are a number of parameters like cutting speed, feed and depth of cut etc. which must be given consideration during the machining. The prediction of optimal machining conditions for good surface roughness and material removal rate plays a very important role in process planning.

Keyword : Grey relational analysis; Multi-objective optimization; Taguchi Method; CNC machining.

Introduction

CNC stands for Computer Numerically Controlled. It is the method of controlling a machine tool by the application of digital electronic computers and circuitry using alpha- numerical data. Machine movements (actuated and controlled by cams, gears, levers, or screws) are directed by computers and digital circuit.

Turning is a widely used machining process in which a single- point cutting tool removes material from the surface of a rotating cylindrical workpiece. Three cutting parameters, i.e., feed rate, depth of cut, and insert radius must be determined in a turning operation. A common method of evaluating machining performance in a turning operation is based on the surface roughness. Basically, surface roughness is strongly correlated with cutting parameters such as insert radius, feed rate, and depth of cut.

Literature Review

An extensive literature review on effect of material removal rate, surface roughness of the work piece in CNC lathe machine is presented in this Chapter. The study of the literature review on basic process parameter on CNC lathe machine such as Material Removal Rate and Surface Roughness, optimized by the various technique. Machining parameters affecting quality characteristics in the machining process is thoroughly studied. Productivity is constantly a matter of concern with a high level of accuracy for any process; rather it is the driver of economic growth of industry. Therefore, it is always desirable to have machining with maximum MRR and minimum surface roughness along with better circularity.

After reading some research paper we found that in lots of case the surface roughness depends upon the three variable parameters like: depth of cut, cutting speed and feed rate. After reading literature paper and discussion with our company operator we found that the surface and tool mostly effected by speed, feed rate and depth of cut. We also found that not more work done on this material AISI 1045 in area of cutting and surface roughness.

Experimentation

3.1 Material

Mild steel has good machinability in normalized as well as the hot rolled condition. Based on the recommendations given by the machine manufacturers, operations like tapping, milling, broaching, drilling, turning and sawing etc. can be carried out on Mild steel using suitable feeds, tool type and speeds.

Mild steel of Ø: 58mm, length: 900mm were used for the turning experiments in the present study.

Element	Content (%)
Carbon	0.16-0.18

Manganese	0.70-0.90
Silicon	0.40
Phosphorous	0.04
Sulphur	0.04

Physical Properties:

Mild steel is very strong due to the low amount of carbon it contains. In materials science, strength is a complicated term. Mild steel has a high resistance to breakage. Mild steel, as opposed to higher carbon steels, is quite malleable, even when cold. This means it has high tensile and impact strength. Higher carbon steels usually shatter or crack under stress, while mild steel bends or deforms.

Mechanical Properties:

Steel is made up of carbon and iron, with much more iron than carbon. In fact, at the most, steel can have about 2.1 percent carbon. Mild steel is one of the most commonly used construction materials. It is very strong and can be made from readily available natural materials. It is known as mild steel because of its relatively low carbon content.

3.2 Experimental Details

The experiments are performed on CNC lathe. The tool and material selected were mild steel. Three process parameters, as already stated above, Cutting speed (A), Feed rate (B) and Depth of cut(C) were considered in the study. Equally spaced five levels within the operating range of the input parameters were selected for each of the process parameters. Based on Taguchi method, an L8 orthogonal array (OA) which has 8 different experiments at two levels was developed. Table 1 shows the design factors along with their levels.

Table 1: Parameters, Codes, and level values used for orthogonal array

Parameters	**Code**	**Levels**	
		1	2
Cutting Speed	A	200	300
Feed	B	0.25	0.3
Depth of Cut	C	0.1	2.5

3.3 Result and Discussion

Taguchi technique is a powerful tool for identification of effect of various process parameters based on orthogonal array (OA) experiments which provides much reduced variance for the experiments with an optimum setting of process control parameters. As referred earlier, in this work L8 orthogonal array was used to carry out the experiments and the experimental results (Table2) were analyzed using Taguchi method.

Table 2: Experimental Result

Exp. No.	**Cutting Speed (m/s)**	**Feed (mm/rev)**	**Depth of Cut (mm)**	**MRR (mm^3/min)**	**S/N (MRR)**	**Ra (µm)**	**S/N (Ra)**
1	200	0.25	0.1	4.28	-3.5980	6.05	-6.60421
2	200	0.25	2.5	75.003	-28.4707	3.78	-2.51894

3	200	0.3	2.5	112.5112	-31.9930	3.05	-0.65510
4	300	0.25	2.5	79.7906	-29.0081	3.55	-1.97367
5	300	0.3	2.5	99.9999	-30.9691	3.03	-0.59795
6	200	0.3	0.1	5.6253	-5.9720	1.84	3.73454
7	300	0.25	0.1	3.7503	-2.4504	1.75	4.17014
8	300	0.3	0.1	4.6153	-4.2531	2.1	2.58651

In order to assess the variability of the results within a pre-defined range, signal to noise ratio (S/N ratio) analysis was done with MRR and Surface roughness as the output. For maximization of MRR the S/N ratio was calculated using larger the better criterion and for minimization of Ra the S/N ratio was calculated using smaller the better criterion. Since the experimental design is orthogonal, it was possible to separate out the effect of each parameter at different levels. The mean S/N ratio for each level of the factors A, B and C was summarized and shown in Table 3. In addition, the total mean S/N ratio for the 8 experiments was also calculated and has been depicted in Table 3. All the calculations were done using Minitab software [18].The response table indicates the average of the selected characteristic for each level of the factors. The response table also includes ranks based on Delta statistics, which compare the relative extent of effects. The Delta statistic is calculated as the difference of the highest average and the lowest average for each factor. Then the Ranks are assigned based on the Delta values. The software assigns rank 1 to the highest Delta value, rank 2 to the second highest, and soon thereafter. The resulting main effects plots for each of the process parameters have been depicted in Fig. 1 and Fig. 2 respectively.

Table 3: Response table of mean S/N ratio

Level	Cutting Speed	Feed	DOC
1	26.518	22.245	3.752
2	24.823	9.096	47.589
Delta	1.695	6.851	43.837
Rank	3	2	1

The total mean S/N ratio are 30.009 dB

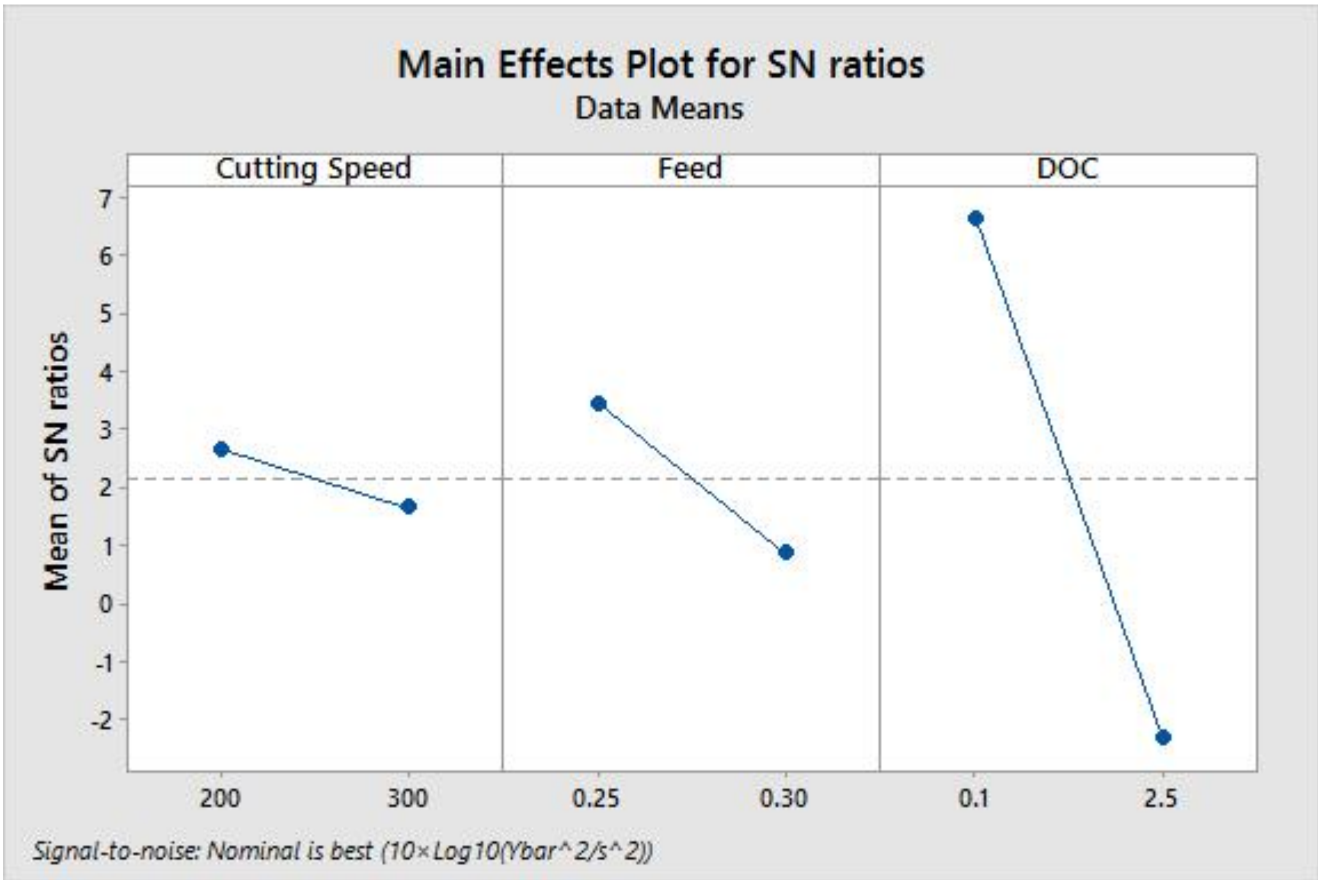


Fig. 1 Main effects plot for mean S/N ratios for MRR & Ra

Since the main effects plot is plotted between the S/N ratio and the various considered values of the input parameters hence if the line for a particular parameter is near horizontal, it indicates that the parameter has no significant effect in the selected range of values. This also indicates that the parameter for which the line has the highest inclination will have the most significant effect. In this work, it is very much clear from the main effects plot that the parameter C (Depth of Cut) and then parameter B (Feed) had the most significant influence on MRR and Surface roughness while parameter A (Cutting Speed) has some or negligible effect. The optimal process parameter combination is the one that yields individual maximum mean S/N ratio and thus the same for maximum MRR is A1B1C1and for Ra is A2B2C2. ANOVA is a statistical technique which provides important conclusions based on analysis of the experimental data. This technique is very useful for revealing the level of significance of the influence of factor(s) or interaction between factors on a particular response. It segregates the total variability of the response into individual contributions of each of the factors and the error. The results are shown in Table 4. ANOVA determines the ratio between the regression mean square and the mean square error and is termed as F-ratio or variance ratio, since it is also the ratio of variance due to the effect of a factor and variance due to the error term, hence the terminology. The ratio is used to measure the significance of each of the parameters under investigation with reference to the variance of all the terms included in the error term at the desired significance level, α. and standard tabulated values are available for comparison. If the calculated value of the F-ratio is higher than the tabulated value of the F-ratio, then the factor is significant at a desired α level and vice versa. In general, when the F value increases the significance of the specific parameter also increases. The ANOVA table (Table 4 & Table 5) shows the percentage contribution of each of the parameters. As discussed earlier for the main effect plots, the same trend can be observed for the various parameters, i.e the parameter C (Depth of Cut) and B (Feed), had the most significant influence on MRR while parameter A (Cutting Speed) was not significant within the specific experimental range.

Table 4: Result of ANOVA (MRR)

Source	DF	SS	MS	F	Contribution
A	1	10.7	10.7	0.09	0.066
B	1	448.8	448.8	3.86	2.778
C	1	15227.6	15227.6	131.03	94.27
Error	4	464.9	116.2		2.87
Total	7	16152.0			100

Table 5: Result of ANOVA (Ra)

Source	DF	SS	MS	F	Contribution
A	1	2.3005	1.3005	1.17	16.71
B	1	3.2640	3.2640	1.66	23.70
C	1	0.3486	0.3486	0.18	6.44
Error	4	7.8564	1.9641		53.15
Total	7	13.7696			100

Final Equation in Terms of Actual Factors:

MRR = 48.20 + 1.16 Cutting Speed_200 - 1.16 Cutting Speed_300 - 7.49 Feed_0.25 + 7.49 Feed_0.30 - 43.63 DOC_0.1 + 43.63 DOC_2.5

Ra=3.144+ 0.536 Cutting Speed_200- 0.536 Cutting Speed_300+ 0.639 Feed_0.25- 0.639 Feed_0.30 - 0.209 DOC_0.1 + 0.209 DOC_2.5

Optimization using GRA

4.1Grey Relation Analysis (GRA)

Now-a-days, multi criterion decision-making (MCDM) techniques are gaining significance for complex genuine issues because of their inalienable capacity to judge distinctive choices on different criteria for conceivable determination of the best. In this paper, a multi-criteria decision making model combining with grey relational analysis (GRA) has been proposed to study the optimization problem in WEDM process. The methodology consists of a number of steps as follows:

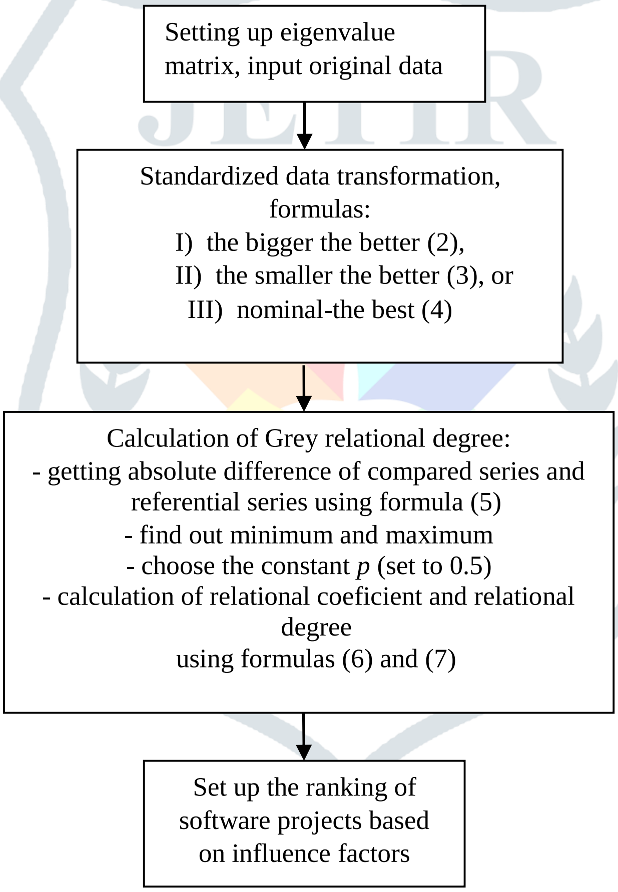
Let the number of the listed software projects be *m*, and the number of the influence factors be *n*. Then a *m* x *n* value matrix (called eigenvalue matrix) is set up.

$$X = \begin{bmatrix} x_1(1), x_1(2), \ldots\ldots x_1(n) \\ x_2(1), x_2(2), \ldots\ldots x_2(n) \\ \ldots\ldots \\ \ldots\ldots \\ x_m(1), x_m(2), \ldots\ldots x_m(n) \end{bmatrix} \quad (1),$$

where $x_i(k)$ is the value of the number *i* listed project and the number *k* influence factors.

Usually, three kinds of influence factors are included, they are:

1. Benefit – type factor (the bigger the better),
2. Defect – type (the smaller the better)
3. Medium – type, or nominal-the-best (the nearer to a certain standard value the better).



(fig. 2. the generation of grey relation degree for software projects**)**

It is difficult to compare between the different kinds of factors because they exert a different influence. Therefore, the standardized transformation of these factors must be done. Three formulas can be used for this purpose.

$$x_i(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)} \quad (2).$$

The first standardized formula is suitable for the benefit – type factor.

$$x_i(k) = \frac{\max x_i(k) - x_i(k)}{\max x_i(k) - \min x_i(k)} \quad (3).$$

The second standardized formula is suitable for defect – type factor.

$$x_i(k) = \frac{|x_i(k) - x_0(k)|}{\max x_i(k) - x_0(k)} \quad (4).$$

The third standardized formula is suitable for the medium – type factor.

The grey relation degree can be calculated by steps as follows:

a) The absolute difference of the compared series and the referential series should be obtained by using the following formula:

$$\Delta x_i(k) = |x_0(k) - x_i(k)| \quad (5),$$

and the maximum and the minimum difference should be found.

b) The distinguishing coefficient *p* is between 0 and 1. Generally, the distinguishing coefficient *p* is set to 0.5.
c) Calculation of the relational coefficient and relational degree by (6) as follows.

In Grey relational analysis, Grey relational coefficient ξ can be expressed as follows:

$$\xi_i(k) = \frac{\Delta \min + p\Delta \max}{\Delta x_i(k) + p\Delta \max} \quad (6),$$

and then the relational degree follows as:

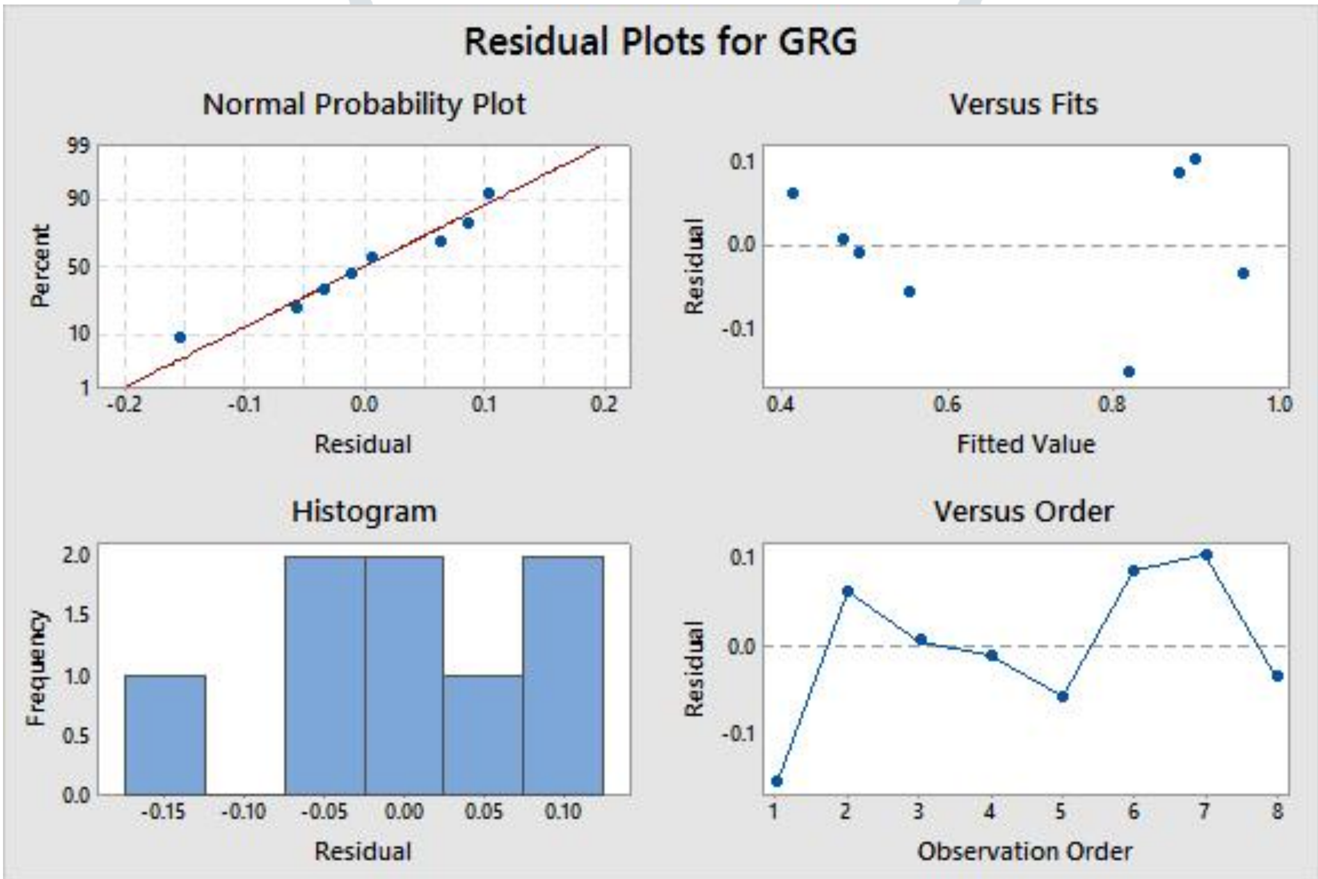
$$r_i = \sum [w(k)\xi(k)] \quad (7).$$

In equation (7), ξ is the Grey relational coefficient, *w (k)* is the proportion of the number *k* influence factor to the total influence indicators. The sum of *w (k)* is 100%. The result obtained when using (6) can be applied to measure the quality of the listed software projects.

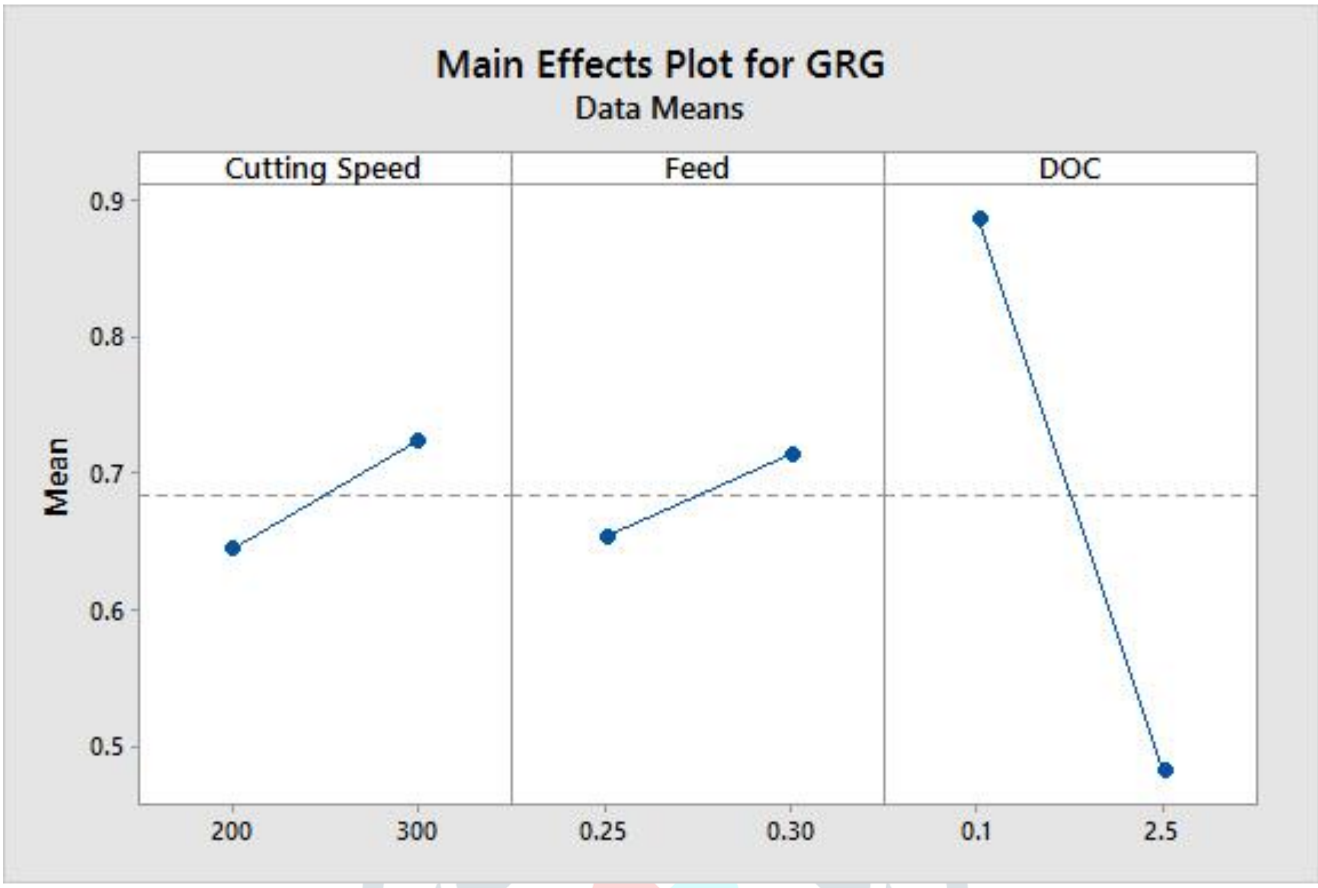
6.2Result and Discussion

Exp. No.	**MRR**	**Deviation (MRR)**	**Grey Relation Coefficient (MRR)**	**Ra**	**Deviation (Ra)**	**Grey Relation Coefficient (Ra)**
1	4.28	0.0049	0.9904	6.05	1.0000	0.3333
2	75.003	0.6551	0.4329	3.78	0.4721	0.5144
3	112.5112	1.0000	0.3333	3.05	0.3023	0.6232
4	79.7906	0.6992	0.4170	3.55	0.4186	0.5443
5	99.9999	0.8850	0.3610	3.03	0.2977	0.6268
6	5.6253	0.0172	0.9667	1.84	0.0209	0.9598
7	3.7503	0.0000	1.0000	1.75	0.0000	1.0000
8	4.6153	0.0080	0.9843	2.1	0.0814	0.8600

MRR	Ra	Grey Relation Grade	Rank
4.28	6.05	0.6618	4
75.003	3.78	0.4736	8
112.5112	3.05	0.4783	7
79.7906	3.55	0.4806	6
99.9999	3.03	0.4939	5
5.6253	1.84	0.9632	2
3.7503	1.75	1.0000	1
4.6153	2.1	0.9222	3



(**fig. 3** residual plot for GRG)



(**Fig. 4** Main effect plot for GRG)

According to software the optimal parameter for experiment are
Cutting Speed = 300 (m/s) Feed = 0.25 (mm/rev) Depth of Cut = 0.1 (mm)

Conclusion

- The experimental results showed that the Taguchi parameter design is an effective way of determining the optimal cutting parameters for achieving low surface roughness.
- The Machining Parameters namely cutting speed, Feed rate, depth of cut is optimized to meet the objectives. The results reveal that the primary factor affecting the surface roughness is speed, subsequently followed by feed and depth of cut.
- The Depth of cut is the most significant factor which contributes to the MRR 94.27% subsequently followed by feed which contributes 2.778% and Cutting speed has least significant factor contributes 0.066%. The Feed is the most significant factor which contributes to the Surface roughness 23.70% subsequently followed by cutting speed which contributes 16.71% and depth of cut has least significant factor contributes 6.44%.
- The optimized factor for minimizing the Surface roughness Ra and maximizing MRR is Cutting speed = 300m/s, Feed = 0.25 mm/rev, Depth of cut = 0.1mm.

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