Parametric analysis and multi objective optimization of cutting parameters in turning operation of AISI 4340 using GRA

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Abstract

Now a days, main challenges to metal cutting industries are productivity and quality of product or component. The machining parameter of any machining process highly affects the quality of product. Surface roughness is a key indicator to quality of product or component in turning process. In this paper, the effect of machining parameter on surface roughness (Ra, Rz, Rq) in turning of AISI 4340 steel with uncoated carbide tool is investigated. In addition, the optimum setting of machining parameter is found by using grey relational analysis. The machining parameter selected are cutting speed (100, 120, 140m/min), feed rate (0.15, 0.30, 0.45mm/rev) and nose radius (0.4, 0.8, 1.2mm). General full factorial design is used for experimental plan. Furthermore the experimental results are analyzed using Analysis of variance and modeling is carried out using regression analysis.

Keywords: *Surface roughness, AISI4340, GRA, Uncoated carbide*

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INTRODUCTION:

Surface roughness is defined as fine irregularities available in the surface texture, usually including those resulting from the inherent action of the production process, like feed marks produced during the machining process.

The accuracy or tolerance of a machine component is mainly dependent on the surface roughness. A close tolerance dimension requires a very fine finish or low surface roughness which requires multiple machining operations.

The unit of Surface roughness is micrometers or micro inches. It can be measured by using a variety of instruments, including both surface contact and non-contact types. Most widely used technique for measurement of surface roughness in industries is by using a stylus contact-type instrument that provides a numerical value for surface roughness. A stylus contact-type surface measuring instruments can usually provide an indication of surface roughness in terms of the arithmetic average, Ra or root mean square (rms) value Rq[1].

A. Das et al [2] have evaluated the machinability of AISI 4340 alloy steel using a different levels of cutting parameters in dry cutting surroundings. Based on the study they have concluded that the Coated cermets provides better result compared to uncoated carbides inserts(Low cutting force, less flank wear and low workpiece surface temperature) due to coating of cermets inserts.

D. Singh et al [3] have proposed that small change in nose radius will affect the surface roughness by large extent in dry turning of aluminium 6061. They have also concluded that the average surface roughness value will increases with increase in feed rate and cutting speed within a specified range. Also the depth of cut will adversely affect surface finish but in a small extent.

P.K.Sood et al [4] have performed the experiments on AISI 4340 alloy steel using uncoated tungsten carbide inserts under the varying condition of process parameters (e.g., Cutting speed, feed rate, and different cooling conditions).Based on the experiments & optimization performed, authors have concluded that cooling condition is the most significant parameters followed by feed & cutting speed.

W. B. Rashid et al [5] have designed the experiments using the full factorial based Taguchi matrix. After performing the experiments, the variations present in the response data is measured using S/N ratio, and then ANOVA and multiple regression has been carried out on obtained data. Authors have concluded that when feed rate during hard turning approaches very low, it could be most significant parameters.

A. Pathan et al [6] have concluded that for high cutting speed MQL gives poor surface finish compared to flooded lubrication. Machining time is same for both MQL and flooded cutting condition. Feed rate is most influencing parameter for surface roughness followed by cutting speed and depth of cut.

M.K. Gupta et al [7] have discussed effect of cooling method and cutting parameters (cutting speed and feed rate) on cutting force, tool wear and surface roughness. ANOVA and Grey relational analysis are executed to study the effects, significance, percentage contribution and optimum setting for given process parameter. Authors have concluded that the cryogenic cooling is an effective alternative to dry and wet cooling in turning of AISI 4340 steel with coated carbide insert.

M. Adinarayana et al [8] have performed multi objective optimization of turning parameter for turning on AISI 4340 allow steel. Authors have concluded that the cutting speed has highest influence followed by depth of cut on surface roughness. Material removal rate and power consumption have increasing behaviour with increase in speed, feed and depth of cut. Material removal rate has highest influence of cutting speed and depth of cut has highest influence on power consumption.

A. Saini et al [9] presents the influence of approach angle, feed rate, cutting speed and depth of cut on cutting forces and tool tip temperature. Artificial neural network has been used for error prediction in experimental results. After performing experiments authors have conclude that machining using MQL (Minimum Quantity Lubrication) shows beneficial effects compared to dry machining. Authors have also concluded that the PVD coated inserts produces better results compared to CVD coated inserts due to a thin TiAlN layer which provides fine surface for insert, hence it protects the insert from built-up-edge which reduces tool life.

C.O.Izelu et al [10] experimentally investigate the effect of turning parameters on the induced vibration and surface roughness in the turning of 41Cr4 alloy steel using carbide (F30 type) cutting tool. They have concluded that the induced vibration and surface roughness of workpiece is proportional to depth of cut, cutting speed and workpiece overhang.

B.Tulasiramarao et al [11] have performed experiment on two different materials stainless steel and aluminium using HSS steel. Authors have concluded that in case of stainless steel minimum surface roughness is obtained when feed rate and depth of cut are at minimum level and spindle speed at higher level for selected range. While in case of aluminium minimum surface roughness can be obtained by taking all the parameters at minimum level for selected range.

J.M. Varma et al [12] found out that solid lubricant (Hexagonal boron nitride H-bn) is a feasible alternative to cutting fluid. They have concluded that the optimum condition for better surface finish is at cutting speed (151.3 m/min), feed rate (0.4 mm/rev), depth of cut (0.3 mm) and nose radius (0.8 mm). Confirmation test shows that cutting parameter at optimum level in solid lubricant machining the value of surface roughness value is 0.721µm.

S.R.Das et al [13] have concluded that the depth of cut does not affect the surface roughness significantly for studied range of parameters. They have also concluded that the feed rate is most significant parameter (60.85%) followed by cutting speed (24.6%) for surface roughness.

R. Suresh et al [14] have evaluated the performance of multilayer hard coatings (TiC/TiCN/Al2O3) on cemented carbide substrate using chemical vapor deposition (CVD) for machining of hardened AISI 4340 steel. Authors have derived the conclusion as Machining forces are high when the feed & depth of cut is at low level and cutting speed is high level, Machining power and tool wear increases linearly with increase in cutting speed and feed rate, For minimizing the surface roughness, the cutting speed must be kept at high level and feed rate low level.

A. H. Suhail et al [15] have selected response variables for parametric optimization are workpiece surface temperature and surface roughness. They have concluded that the feed rate had strongest influence on surface roughness followed by cutting speed and last by depth of cut, the workpiece surface temperature has strongest influence of depth of cut followed by feed rate and then by cutting speed.

M.Y.Noordin et al [16] have applied the RSM technique in turning of AISI 1045 steel to describe the performance of multilayer tungsten carbide tools. After performing experiments and statistical analysis, authors have concluded that the feed rate is most influencing parameter which affects the surface roughness and tangential force. Side cutting edge angle and interaction of side cutting edge angle and feed rate have secondary contribution.

EXPERIMETAL PROCEDURE:

2.1 Workpiece material:

AISI 4340 alloy steel is selected as a workpiece material in present study. It is one of the most extensively used AISI series material in automobile industries and aerospace engineering. It is also used in manufacturing of bearings, gears, heavy duty shafts, axles, spindles, couplings, Pins, and cams. It has high toughness and strength in the heat treated condition. Table 2.1.1 & Table 2.1.2 shows the chemical composition and properties of AISI 4340 alloy steel.

Table 2.1.1: *Chemical composition of AISI 4340 alloy steel*

Alloying Element	Fe	Ni	Cr	Mn	C	Mo	Si	S	P
Content (%)	95.195 - 96.330	1.65 - 2.00	0.700 - 0.900	0.600 - 0.800	0.370 - 0.430	0.200 - 0.300	0.150 - 0.300	0.0400	0.0350

Table 2.1.2: *Properties of AISI 4340 alloy steel*

Type of Property	**Properties**	**Metric**
Physical Properties	Density	7.85 g/cm^3
	Melting point	1427°C
Mechanical Properties	Tensile strength	745 Mpa
	Hardness (Brinell)	217
	Elongation at break	22%
Thermal Properties	Co-efficient of Thermal expansion (20°C/68°F, specimen oil hardened, 600°C)	12.3 µm/m°C
	Thermal conductivity	44.5 W/mK

2.2 Cutting tools:

Cutting tools selected in present study are uncoated carbide single point cutting tool with different nose radius (0.4, 0.8 & 1.2 mm)

2.3 Experimental Work:

Turning test of AISI 4340 steel were carried out on a conventional medium duty lathe machine under dry condition. Surface roughness was measured by Mitutoyo SJ-201 surface roughness tester. Mitutoyo SJ - 201 is a shop-floor type surface roughness measuring instrument, which traces the surfaces of various machines parts, calculates their surface roughness based on roughness standards, and displays the results. Detail of experimental work is given in table *.3.

Table 2.3: Experiments detail

Machine tool	Lathe machine (Maruti machine tool Ltd.)
Work piece material	AISI 4340 steel
Size (Intial)	Φ55 x 250 mm
Cutting tool	Uncoated carbide tool (Brazed)
Surface roughness tester	Mitutoyo SJ – 201

Cutting condition	Dry
Depth of cut	0.5 (Constant)

2.4 Design of experiments:

In this study, three controllable variables, namely, cutting speed (m/min), feed rate (mm/rev) and nose radius (mm). Depth of cut is taken as 0.5 mm constant throughout the experimental work. Design of experiment is carried out using each machining parameter at three levels as shown in table 2.4.1.

Table 2.4.1: Parameters and their levels

Parameter	Unit	Levels		
		1	2	3
Cutting speed	m/min	100	120	140
Feed rate	mm/rev	0.15	0.30	0.45
Nose radius	mm	0.4	0.8	1.2

The experimental design of full factorial design of experiments is carried out using MINITAB (Version 17). Based on general full factorial design 27 experimental runs are required. General full factorial design for 27 experiments & Responses is given in Figure 2.4.1.

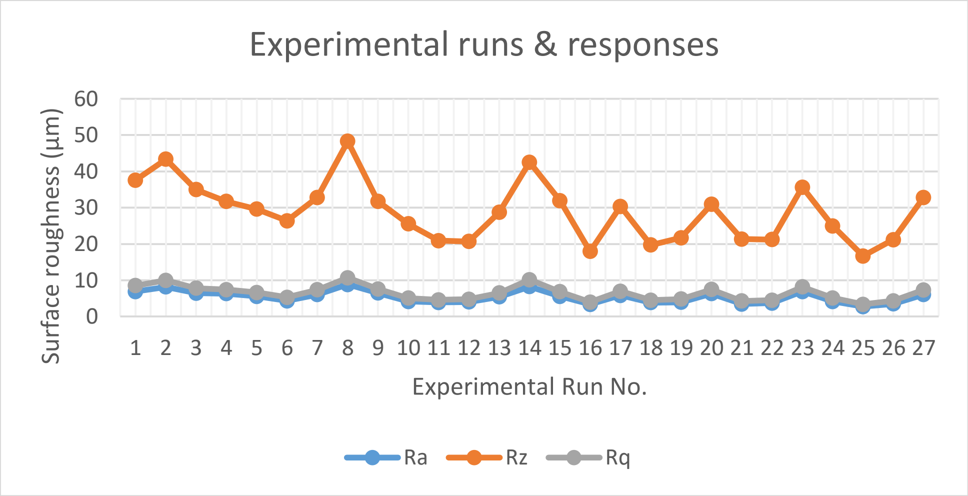


Figure 2.4.1: Experimental run & Responses

RESULTS & DISCUSSIONS:

3.1 ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences among group means and their associated procedures (such as "variation" among and between groups). Anova gives significant input variable for selected experiment results. Also examine interactions between independent variables. In present work, Anova is performed at 95% confidence level. Anova for response variable are shown in table *.*.*,*.*.* & *.*.*. From the results of anova it is clear that feed rate is most significant parameter followed by nose radius for all the response variables. Cutting speed is the least significant parameter for all the response variables compared to other independent variables.

3.1.1 ANOVA FOR Ra

Table 3.1.1: Anova table for Ra

Source	DF	Seq SS	Seq MS	F- value	P - Value	Contribution (%)
Cutting speed	2	0.2102	0.1051	0.13	0.880	0.29
Feed rate	2	37.7043	18.8521	23.37	0.000	52.73
Nose radius	2	16.8318	8.4159	10.43	0.006	23.54
Cutting speed * Feed rate	4	0.4578	0.1145	0.14	0.962	0.64
Cutting speed * Nose radius	4	5.3440	1.3360	1.66	0.252	7.47
Feed rate * Nose radius	4	4.4974	1.1243	1.39	0.319	6.29
Error	8	6.4540	0.8068			9.03
Total	26	71.4994				100
Model summary						
S	R-sq	R-sq (adj)				
0.8982	90.97 %	70.66 %				

3.1.2 ANOVA FOR Rz

Table 3.1.2: ANOVA for Rz

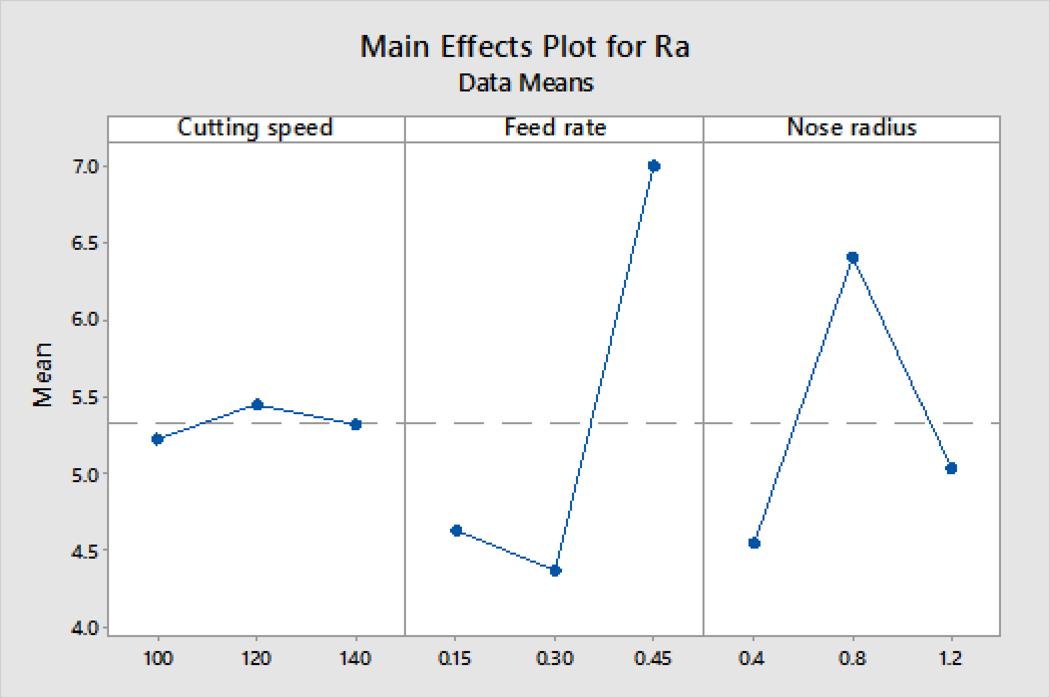
Source	DF	Seq SS	Seq MS	F- value	P - Value	Contribution (%)
Cutting speed	2	3.80	1.900	0.11	0.894	0.22
Feed rate	2	969.32	484.661	29.01	0.000	55.81
Nose radius	2	400.31	200.153	11.98	0.004	23.05
Cutting speed * Feed rate	4	22.55	5.637	0.34	0.846	1.30
Cutting speed * Nose radius	4	116.56	29.140	1.74	0.233	6.71
Feed rate * Nose radius	4	90.53	22.631	1.35	0.330	5.21
Error	8	133.67	16.709			7.70
Total	26	1736.73				100
Model summary						
S	R-sq	R-sq (adj)				
4.0876	92.30 %	74.99 %				

3.1.3 ANOVA FOR Rq

Table 3.1.3: ANOVA for Rq

Source	DF	Seq SS	Seq MS	F- value	P - Value	Contribution (%)
Cutting speed	2	0.151	0.0754	0.07	0.934	0.14
Feed rate	2	57.693	28.8464	26.43	0.000	54.98
Nose radius	2	23.817	11.9083	10.91	0.004	22.70
Cutting speed * Feed rate	4	0.596	0.1490	0.14	0.964	0.57
Cutting speed * Nose radius	4	7.172	1.7929	1.64	0.255	6.83
Feed rate * Nose radius	4	6.779	1.6947	1.55	0.276	6.46
Error	8	8.733	1.0916			8.32

Total	26	104.940				100



Model summary						
S	R-sq	R-sq (adj)				
1.0448	91.68 %	72.95 %				

3.2 Graph plot

Figure 3.2.1: Main effect plot for average arithmetic surface roughness Ra

It has been seen from figure 3.2.1 that when cutting speed increases from 100 to 120 m/min surface roughness value is increases up to middle level and then decreases for 120 to 140 m/min. for feed rate from 0.15 to 0.30 mm/rev. surface roughness value is decreases and for 0.30 to 0.45 mm/rev. it will abruptly increases. Surface roughness is increases for 0.4 to 0.8mm and then it will decreases.

Figure 3.2.2: Interaction effect plot for average arithmetic surface roughness Ra

Interaction effect of one variable with other variable on response variable can be investigated from figure 3.2.2.

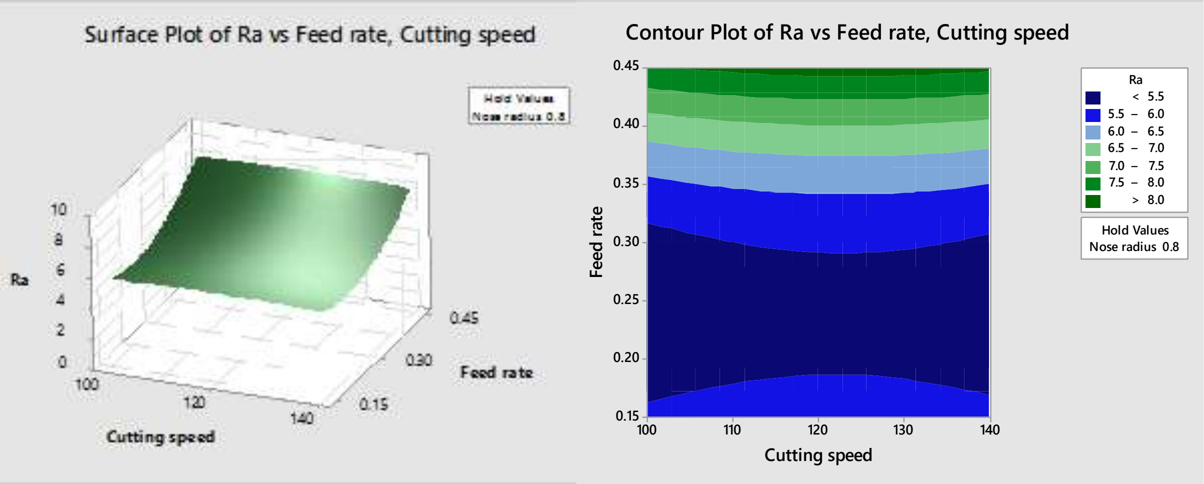
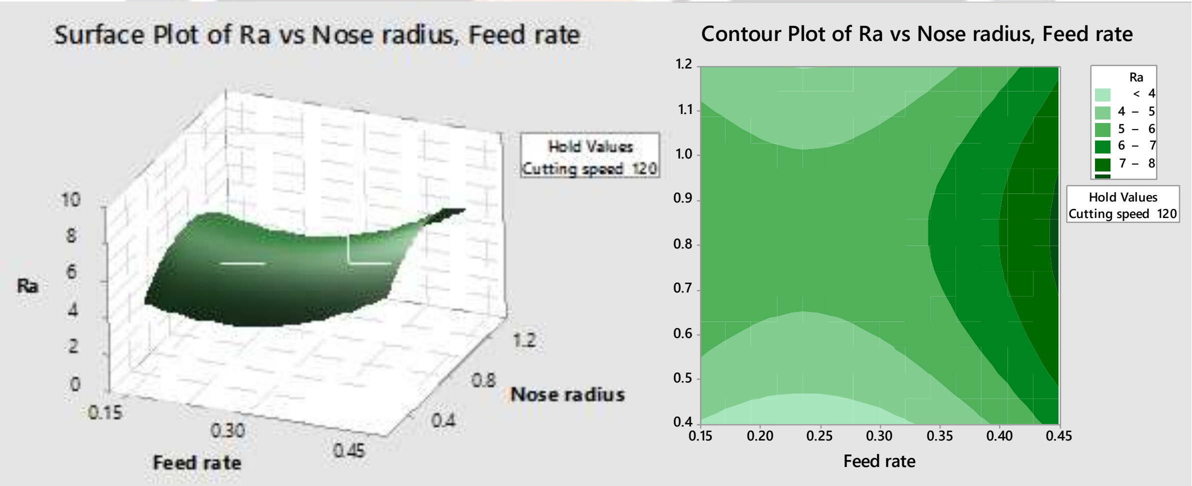


Figure 3.2.3: Surface plot & contour plot for Ra verses Feed rate & cutting speed



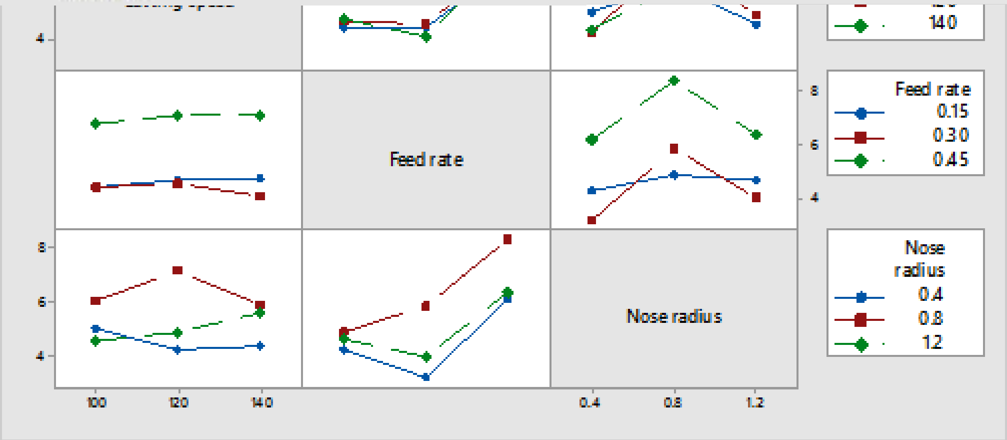


Figure 3.2.4: Surface plot & contour plot for Ra verses Feed rate & Nose radius

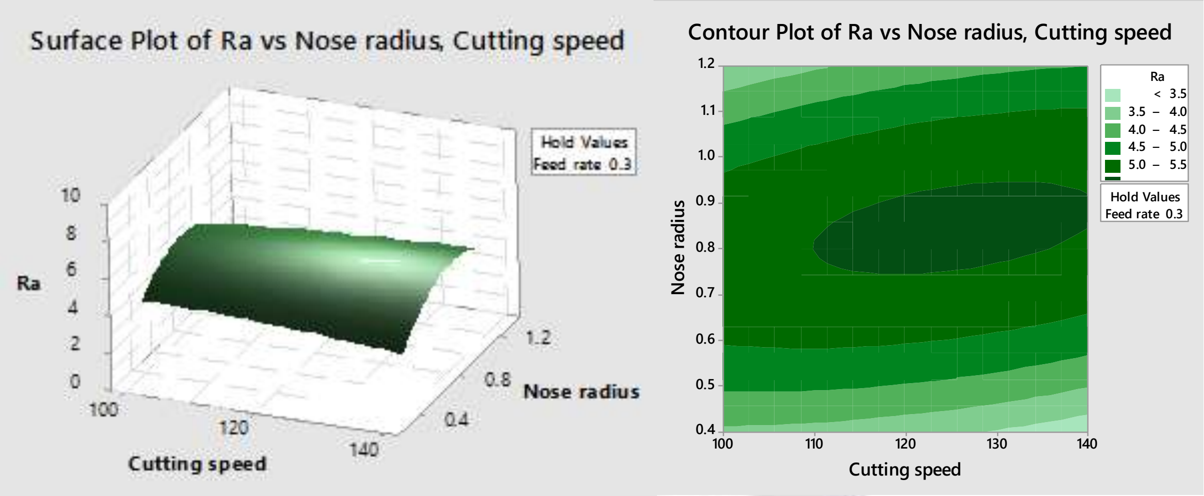


Figure 3.2.5: Surface plot & contour plot for Ra verses Nose radius & Cutting speed

In figure 3.2.3 minimum surface roughness is observed when feed rate from 0.15 to 0.30 mm/rev and throughout the range of cutting speed. Figure 3.2.4 shows for lower level of feed rate and nose radius minimum surface roughness can be obtained. Figure 3.2.5 depicts that at maximum level of cutting speed and minimum level of nose radius best surface finish can be obtained.

3.3 REGRESSION ANALYSIS

Regression analysis is carried out on the obtained results by considering quadratic model. Following are the regression equations for response variables:

Ra = 0.8 + 0.059 Cutting speed - 30.9 Feed rate + 10.67 Nose radius - 0.000421 Cutting speed*Cutting speed + 64.1 Feed rate*Feed rate - 10.12 Nose radius*Nose radius + 0.0064 Cutting speed*Feed rate + 0.0528 Cutting speed*Nose radius - 0.64 Feed rate*Nose radius

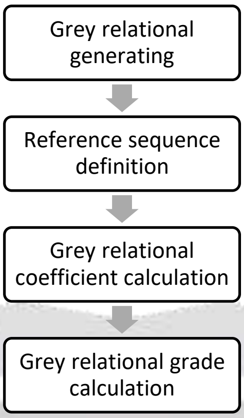
Rz = 35.0 - 0.23 Cutting speed - 151.2 Feed rate + 56.7 Nose radius + 0.00032 Cutting speed*Cutting speed + 349.9 Feed rate*Feed rate - 50.2 Nose radius*Nose radius - 0.076 Cutting speed*Feed rate + 0.250 Cutting speed*Nose radius - 14.1 Feed rate*Nose radius

Rq = 3.9 + 0.016 Cutting speed - 36.6 Feed rate + 13.19 Nose radius - 0.00026 Cutting speed*Cutting speed + 80.4 Feed rate*Feed rate - 12.13 Nose radius*Nose radius - 0.003 Cutting speed*Feed rate + 0.0624 Cutting speed*Nose radius - 2.07 Feed rate*Nose radius

By reducing the equations in terms of significant coefficients and main effect terms

Ra = 0.8 + 0.059 Cutting speed - 30.9 Feed rate + 10.67 Nose radius + 64.1 Feed rate*Feed rate - 10.12 Nose radius*Nose radius

Rz = 35.0 - 0.23 Cutting speed - 151.2 Feed rate + 56.7 Nose radius + 349.9 Feed rate*Feed rate - 50.2 Nose radius*Nose radius



Rq = 3.9 + 0.016 Cutting speed - 36.6 Feed rate + 13.19 Nose radius + 80.4 Feed rate*Feed rate - 12.13 Nose radius*Nose radius

3.4 GREY RELATIONAL ANALYSIS

The procedure of gray relational analysis starts with translating the performance of all alternatives into a comparability sequence. This step is called gray relational generating. Based on these sequences, a reference sequence (ideal target sequence) is defined. Then, the grey relational coefficient between all comparability sequences and the reference sequence is calculated. Finally, based on these grey relational coefficients, the grey relational grade between the reference sequence and every comparability sequences is calculated. If a comparability sequence translated from an alternative has the highest grey relational grade between the reference sequence and itself, that alternative will be the best choice. The procedures of grey relational analysis are shown in Fig. 3.4.1.

Figure 3.4.1: Procedure for Gray relational analysis

The details of the proposed GRA procedure step-by-step presented below:

Step 1: Gray relational generating

It is also called as normalization. It is used to transforms the sequence of measured performance into a comparability sequence. It is required to perform because of following reasons:

- In many of the problems the unit in which performance is measured are different for different attributes
- Some performance attributes have a very large range due to which influence of some performance attributes may be neglected

For a Gray problem, if there are m alternatives and n attributes, the ith alternative can be expressed as Yi = (yi1, yi2, . . ., yij,. . ., yin), where yij is the performance value of attribute j of alternative i. The term Yi can be translated into the comparability sequence Xi = (xi1, xi2, . . ., xij,. . ., xin)

$$Xij = \frac{yij - Min\,\{yij, i=1,2,\ldots\ldots,m\}}{Max\,\{yij, i=1,2,\ldots\ldots,m\} - Min\{yij, i=1,2,\ldots\ldots,m\}} \text{ for } i = 1,2,\ldots..m \;\; j = 1,2,\ldots..n \qquad (1)$$

$$Xij = \frac{Max\,\{yij, i=1,2,\ldots\ldots,m\} - yij}{Max\,\{yij, i=1,2,\ldots\ldots,m\} - Min\{yij, i=1,2,\ldots\ldots,m\}} \text{ for } i = 1,2,\ldots..m \;\; j = 1,2,\ldots..n \qquad (2)$$

$$Xij = \frac{|\, yij - y*j \,|}{Max\,\{yij, i=1,2,\ldots\ldots,m\} - Min\{yij, i=1,2,\ldots\ldots,m\}} \text{ for } i = 1,2,\ldots..m \;\; j = 1,2,\ldots..n \qquad (3)$$

by use of one of Eqs. 1, 2, 3.

Eq. (1) is used for the-larger-the-better attributes, Eq. (2) is used for the-smaller-the-better attributes and Eq. (3) is used for the closer to the desired value yj the better. Here in present paper the response surface roughness have the smaller the better attributes. So by using eq. (2) we get the normalized value of response as shown in table 3.4.1

Step 2: Reference sequence definition

After the grey relational generating procedure using Eq. (1), (2) or Eq. (3), all performance values will be scaled into [0, 1]. For an attribute j of alternative i, if the value xij which has been processed by grey relational generating procedure, is equal to 1, or nearer to 1 than the value for any other alternative, that means the performance of alternative i is the best one for the attribute j. Therefore, an alternative will be the best choice if all of its performance values are closest to or equal to 1. However, this kind of alternative does not usually exist. We can define the reference sequence X0 as (x01, x02, . . ., x0j, . . ., x0n) = (1,1, . . .,1,. . .,1), and then aims to find the alternative whose comparability sequence is the closest to the reference sequence.

Step 3: Grey relational coefficient calculation

Grey relational coefficient is used for determining how close xij is to x0j. The larger the grey relational coefficient, the closer xij and x0j are. The grey relational coefficient can be calculated by Eq. (4).

$$\Upsilon(xoj, xij) = \frac{\Delta \min + \xi\, \Delta max}{\Delta ij + \xi\, \Delta max} \qquad \text{for } i = 1,2,\ldots..m \;\; j = 1,2,\ldots\ldots n \qquad (4)$$

In Eq. (4), ϒ(xoj, xij) is the grey relational coefficient between xij and xoj, and

$$\Delta ij = |\, xoj - xij \,|$$

$$\Delta min = Min\{\Delta ij, i = 1,2, \ldots\ldots, m; j = 1,2, \ldots\ldots n\}$$

$$\Delta max = Max\{\Delta ij, i = 1,2, \ldots\ldots, m; j = 1,2, \ldots\ldots n\}$$

ξ is the distinguishing coefficient, ξ ϵ [0,1]

The purpose of the distinguishing coefficient is to expand or compress the range of the grey relational coefficient. For example, take the case where there are three alternatives, ‘‘a’’, ‘‘b’’ and ‘‘c’’. If ∆aj = 0.1, ∆bj = 0.4 and ∆cj = 0.9, its means that for attribute j, alternative ‘‘a’’ is the closest to the reference sequence. After grey relational generating using Eq. (1)–(3), ∆max will be equal to 1 and ∆min will be equal to 0. Fig. 2 shows the grey relational coefficient results when different distinguishing coefficients are adopted.

In Fig. 2, the differences between ϒ(x0j, xaj), ϒ(x0j,xbj) and ϒ(x0j, xcj) always change when different distinguishing coefficients are adopted, but no matter what the distinguishing coefficient is, the rank order of ϒ(x0j, xaj), ϒ(x0j, xbj) and ϒ(x0j, xcj) is always the same. The distinguishing coefficient can be adjusted by the decision maker exercising judgment, and different distinguishing coefficients usually produce different results of GRA.

By using equation no.4, the grey relational coefficient is calculated as shown in table 3.4.1

Step 4: Grey relational grade calculation

After calculating the entire grey relational coefficient ϒ (x0j, xij), the grey relational grade can be then calculated using Eq. (5).

$$\Gamma\ (Xo, Xi) = \sum_{j=1}^{n} wj\ \gamma(xoj, xij) \qquad \text{for i=1, 2,…., m} \qquad (5)$$

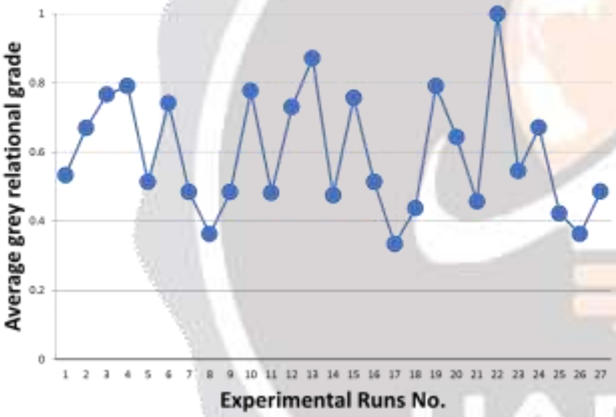
As mentioned above, on each attribute, the reference sequence represents the best performance that could be achieved by any among the comparability sequences. Therefore, if a comparability sequence for an alternative gets the highest grey relational grade with the reference sequence, it means that the comparability sequence is most similar to the reference sequence, and that alternative would be the best choice.

From figure 3.4.2 it can be concluded that for experiment run no. 22 highest grey relational grade is observed. For experiments no.22 the setting of input parameters is cutting speed at level 1 (100m/min), feed rate at level 1 (0.15mm/rev) and nose radius at level 3 (1.2mm).

Table 3.4.1: Grey relational analysis table

Comparability sequence	Reference sequence			Grey relational coefficient			Grey relational grade	Rank
	Ra	Rz	Rq	Ra	Rz	Rq		
	1	1	1					
No.1	0.5362	0.5918	0.5537	0.5188	0.5505	0.5284	0.5326	14
No.2	0.7697	0.7196	0.7673	0.6847	0.6407	0.6825	0.6693	11
No.3	0.8405	0.8573	0.8422	0.7581	0.7779	0.7601	0.7654	6
No.4	0.8766	0.8585	0.8667	0.8021	0.7795	0.7895	0.7904	4
No.5	0.4951	0.5680	0.5075	0.4975	0.5365	0.5038	0.5126	16
No.6	0.7862	0.8731	0.8095	0.7005	0.7976	0.7241	0.7407	8
No.7	0.4572	0.4896	0.4503	0.4795	0.4948	0.4763	0.4836	19
No.8	0.0921	0.1820	0.0762	0.3551	0.3794	0.3512	0.3619	26
No.9	0.4556	0.4892	0.4585	0.4787	0.4947	0.4801	0.4845	18
No.10	0.8191	0.9047	0.8408	0.7343	0.8400	0.7585	0.7776	5
No.11	0.4112	0.5241	0.4449	0.4592	0.5123	0.4739	0.4818	20
No.12	0.8059	0.8415	0.7986	0.7204	0.7593	0.7129	0.7308	9
No.13	0.8997	0.9604	0.9143	0.8329	0.9267	0.8537	0.8711	2
No.14	0.3865	0.5225	0.4231	0.4490	0.5115	0.4643	0.4749	21

No.15	0.8141	0.8661	0.8327	0.7290	0.7888	0.7492	0.7557	7
No.16	0.5362	0.5180	0.5224	0.5188	0.5092	0.5115	0.5131	15
No.17	0.0000	0.0000	0.0000	0.3333	0.3333	0.3333	0.3333	27
No.18	0.3174	0.3997	0.3442	0.4228	0.4544	0.4326	0.4366	23
No.19	0.8799	0.8519	0.8707	0.8064	0.7715	0.7946	0.7908	3
No.20	0.7401	0.6934	0.7333	0.6580	0.6199	0.6522	0.6433	12
No.21	0.3931	0.4218	0.3946	0.4517	0.4638	0.4523	0.4559	22
No.22	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1
No.23	0.5576	0.6199	0.5701	0.5305	0.5681	0.5377	0.5455	13
No.24	0.7648	0.7383	0.7578	0.6801	0.6564	0.6737	0.6701	10
No.25	0.3141	0.3389	0.2966	0.4216	0.4306	0.4155	0.4226	24
No.26	0.1053	0.1566	0.0980	0.3585	0.3722	0.3566	0.3624	25
No.27	0.4145	0.5500	0.4395	0.4606	0.5263	0.4715	0.4861	17



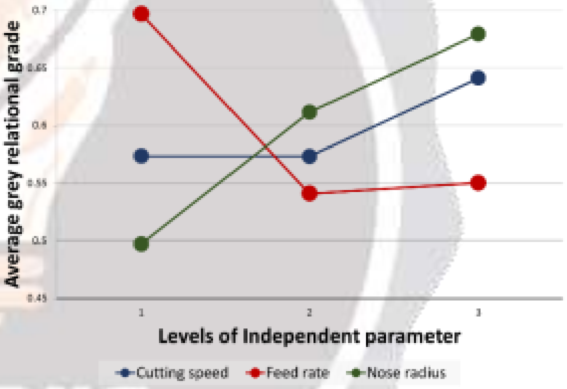


Figure 3.4.2: Average grey relational grade versus Experimental run

Figure 3.4.3: Average grey relational grade vs Levels of Independent parameters

Figure 3.4.3 shows the average grey relational grade with respect to levels of input variables or parameters. Grey relational grades shows the correlation between reference and comparable sequence. So the choice of value of grey relational grade must as high as possible. From figure 3.4.3 cutting speed has highest grey relational grade at level 3, Feed rate has highest grey relational grade at level 1 and nose radius has highest grey relational grade at level 3.

CONCLUSIONS:

In this paper, the effect of machining parameter Cutting speed (100, 120 140 m/min), Feed rate (0.15, 0.30, 0.45 mm/rev) and nose radius (0.4, 0.8, 1.2 mm) on surface roughness (Ra, Rz, Rq) has been investigated.

After performing experiments the result is analyzed by Analysis of variance, modelling of result is carried out using regression analysis and multi objective optimization is performed using grey relational analysis (GRA).

Anova results shows that surface roughness is mainly affected by feed rate (Approximately 55%). Nose radius provides secondary contribution and cutting speed has the least effect. Also the r-square value for all response variables are high (Approx. 90%).

From graph plot it is concluded that surface roughness has almost linear behavior with respect to cutting speed. Whereas it will abruptly increase for higher feed rate in selected range of cutting parameter and for nose radius the surface roughness in increase upto middle level and then decreases.

It is concluded that grey relational analysis can be effectively used for multi objective optimization. The graph for average grey relational grade vs experimental run shows highest value for experiment no. 22.

Optimum parameters found using grey relational analysis is cutting speed 100m/min (level 1), feed rate 0.15mm/rev (level 1) and nose radius 1.2mm (level 3).

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