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STUDY OF EXPERIMENTAL, GEOMETRICAL AND REGRESSION VALUES OF SURFACE ROUGHNESS (RA) WHILE TURNING OF AA7075

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ABSTRACT

The use of coolants while machining was reduced because of the problems encountered by it like environmental pollution, health hazards and high setup costs. The present work, deals with the comparison of experimental, geometrical and regression values of surface roughness during CNC turning of AA7075 steel with tungsten carbide tool. The experiments were done on CNC lathe as per Taguchi's standard L9 (3^3) orthogonal array. Cutting speed, feed and depth of cut were taken as inputs at three different levels and surface roughness characteristics Ra, Rq and Rz were considered as outputs. Mathematical models were developed for Ra, Rq and Rz using the MINITAB-16 software and good correlation was found between input parameters and the output characteristics. Hence the models prepared can be used for better prediction of the responses. ANOVA was employed to test the significance of the model prepared. Finally, the experimental values were compared with both the regression and available geometrical model values and the comparison plots were drawn using EXCEL

INTRODUCTION

Turning operation using a single point cutting tool is one of the oldest and popular methods of metal cutting. Achieving a good surface quality is an important aspect of machining operations. Surface quality plays a major role in the performance of dry, turning because it improves fatigue strength, corrosion resistance and creep life. Surface roughness also affects on some functional attributes of parts like surface friction, wear, light reflection and ability to hold lubricant etc. The quality of machining depends on several factors such as cutting conditions (speed, feed and depth of cut), tool variables (type of material and tool nomenclature) and tool variables (Mechanical and chemical properties of materials). Surface roughness, most commonly refers to the variations in the height of the surface relative to a reference plane. The most commonly used surface roughness parameters are R_a, R_q and R_z are very significant from contact stiffness, fatigue strength and surface wear point of view of machined components. Arithmetic average roughness (R_a) is defined as the average values of ordinates from the mean value. R_a is measured using formulae, $R_a = \frac{1}{n}\sum_{i=1}^{n}|Yi|$; where Y_i is deviation and n is the total number of deviations. Root mean square (R_q) roughness is defined as the square root of the arithmetic mean of the values of the squares of the ordinates of the surface measured from a mean line. R_q is measured using formulae, $R_q = \sqrt{\frac{1}{n}\sum_{i=1}^{n}|Y_i|}$. Ten point height ($R_z$) roughness is defined as it is the average difference between the five highest peaks and five lowest valleys of the surface texture within the sampling length. R_z is measured using formulae, $R_z = \frac{1}{5}\sum_{i=1}^{5} R_{pi} - R_{vi}$; where R_{pi} and R_{vi} are the I^{th} highest peak and lower valleys respectively.

In the present work, an investigation has been done to study the influence of cutting parameters (speed, feed and depth of cut) on surface quality characteristics (R_a, R_q and R_z). For the experiments, traditional Taguchi method has been employed. Taguchi method is one of the most popular and commonly used optimization processes in solving modern engineering problems. Taguchi specifies a special design called Orthogonal Array (OA), it is used to reduce the total number of experiments to be done and overall experimentation cost. For the present study, AA7075 has been considered as work piece and the experiments were done as per standard Taguchi's L9 Orthogonal Array. AA7075 is a subcategory of 7075 series Aluminum Alloy. It has applications in marine and automobile industries. It is used for aircraft fittings, gears & shafts, fuse parts, meter shafts, missile parts, regulating valve parts, worm gears, keys, aircraft, aerospace and defense applications, bike frames, all terrain vehicle sprockets etc. The present study mainly concentrates on comparison of experimental, geometrical and

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regression values of surface roughness (R_a). In case of geometric model $R_a = 0.0321*\frac{f^2}{r}$; where, f is feed rate in mm/rev and r is nose radius in mm. The geometrical model only considering feed and nose radius and roughness value is proportional to square of feed rate and inversely proportional to nose radius of the cutting tool. Since the geometrical model not considering all the factors which are affecting the surface roughness the mathematical models were developed. These models will consider all the process parameters which ever used for the experimentation. MINITAB-16 software is used to develop the mathematical models of the responses. Regression model provides the information about the relationship between input process parameters and output characteristics. ANOVA has been done to check the significance of the model prepared. The assumptions of ANOVA like Normality and constant variance were checked with the help of normal probability and versus fits plots of residuals. The experimental, geometrical and predicted values of R_a were compared and the comparison plots were drawn. % Errors between Experimental (Vs.) Geometrical and Experimental (Vs.) Regression values were calculated and it is found that the errors were less in case of regression as that of geometrical values.

EXPERIMENTAL DETAILS

In the present work, the experiments were conducted as per traditional Taguchi's L9 Orthogonal array on CNC lathe: DX200, JOBBER XL. Aluminium 7075 shown in the figure 1 was used as work piece having dimensions of 30mm diameter and of 60mm length. The chemical composition and mechanical properties of AA7075 were given in the tables 1 and 2. Surface roughness of machined components was taken at three different points with a SJ-301 Mitutoyo gauge and the average value has been considered as the final value.

Fig 1: AA7075 Workpiece

Table 1: Chemical Composition of AA7075 Steel

Element	Al	Zn	Cu	Cr	Fe	Mg	Mn
Wt %	87.1-91.4	5.1-6.1	1.2-2.0	0.18-0.28	0.5 max	2.1-2.9	0.3 max

Table 2: Mechanical Properties of AA7075 Steel

Parameter	Ultimate Tensile Strength (psi)	Yield Strength (psi)	Brinell (BHN)	Rockwell	Density (gm/cm^3)
Value	83000	73000	150	1387	2.8

METHODOLOGY

Taguchi experimental design method is a powerful tool for solving engineering problems was developed by Taguchi. This method uses a special design called Orthogonal Array (OA) to study the entire parametric space with a small number of experiments and hence reduces the total experimentation cost. For the present study, Taguchi standard L9 OA (3level * 3 parameters) has been employed. The selected process parameters with their corresponding levels and L9 OA with actual experimental values were given in the tables 3 and 4 respectively.

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Table 3: Selected Parameters with Their Levels

Parameter	units	Level-1	Level-2	Level-3
Speed (v)	rpm	1000	1500	2000
Feed (f)	mm/rev	0.2	0.3	0.4
Depth of cut (d)	mm	0.5	0.75	1

Table 4: L9 Orthogonal Array with Actual Parameters

Run no.	Factor (v)	Actual rpm	Factor (f)	Actual mm/rev	Factor (d)	Actual mm
1	1	1000	1	0.2	1	0.5
2	1	1000	2	0.3	2	0.75
3	1	1000	3	0.4	3	1
4	2	1500	1	0.2	2	0.75
5	2	1500	2	0.3	3	1
6	2	1500	3	0.4	1	0.5
7	3	2000	1	0.2	3	1
8	3	2000	2	0.3	1	0.5
9	3	2000	3	0.4	2	0.75

RESULTS AND DISCUSSIONS

Table 5 shows the experimental results of surface roughness quality characteristics R_a, R_q and R_z for different combinations of experiments.

Table 5: Experimental Results of Surface Roughness Characteristics R_a, R_q and R_z

Run No.	Speed (RPM)	Feed (mm/rev)	Depth of cut (mm)	R_a Avg. (µm)	R_q Avg. (µm)	R_z Avg. (µm)
1	1000	0.2	0.5	2.11	2.446	9.04
2	1000	0.3	0.75	5.023	6.07	22.68
3	1000	0.4	1	9.17	10.5	36.103
4	1500	0.2	0.75	2.036	2.363	8.546
5	1500	0.3	1	7.16	8.27	26.94
6	1500	0.4	0.5	11.59	13.41	43.963
7	2000	0.2	1	3.35	3.87	13.263
8	2000	0.3	0.5	7.25	8.346	26.086
9	2000	0.4	0.75	11.75	13.563	45.376

GEOMETRICAL VALUES OF SURFACE ROUGHNESS

The geometrical model for the surface roughness is given by, $R_a = 0.0321 \times (f^2/r)$, mm, Where, R_a is surface roughness value, f is the feed value in mm/rev and r is nose radius of cutting tool in mm. From the model, it is observed that the surface roughness value is proportional to square of feed rate value and inversely proportional to the nose radius of cutting tool. The geometrical surface roughness values for different experimental feeds were calculated from the model and given in the table 6.

Table 6: Geometrical Values of Surface Roughness R_a

S.No.	Geometrical values of surface roughness (R_a)
1	3.21
2	7.222
3	12.84
4	3.21
5	7.222
6	12.84
7	3.21
8	7.222
9	12.84

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REGRESSION ANALYSIS

The regression models were prepared for the responses by using MINITAB-16 software. For each model of response ANOVA was conducted to test the significance. The assumptions of ANOVA like Normality and Constant variance were checked with the Normal probability and versus fits plots drawn.

The mathematical model for Arithmetic Surface Roughness (R_a) is given by
R_a = -8.29 + 0.00202 v + 41.7 f – 0.85 d

Analysis of variance (ANOVA) was done to check the model significance and given in the table 7. The model is significant because of high correlation coefficient values (R^2 = 98.1%, R^2 (Adj) = 96.9%). Normal probability and versus plots for R_a shown in the figures 2 and 3 representing that the residuals are following normal distribution and do not follow any particular pattern.

Table 7: ANOVA for R_a

Source	DOF	SS	MS	F	P	Remarks
Regression	3	110.647	36.882	85.51	0.000	Significant
Residual Error	5	2.157	0.431			
Total	8	112.803				

S= 0.657992, R^2 = 98.1%, R^2 (Adj) = 96.9%

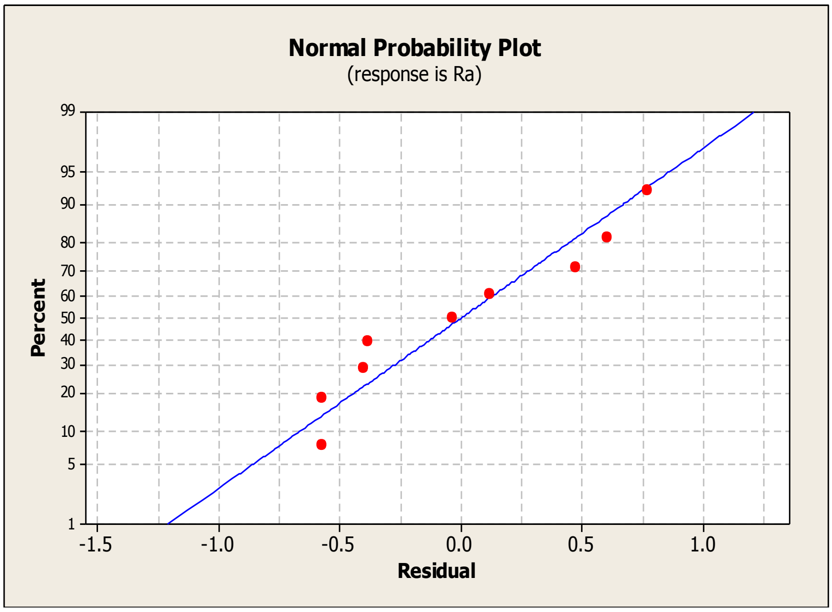

Fig 2: Normal Probability Plot for R_a

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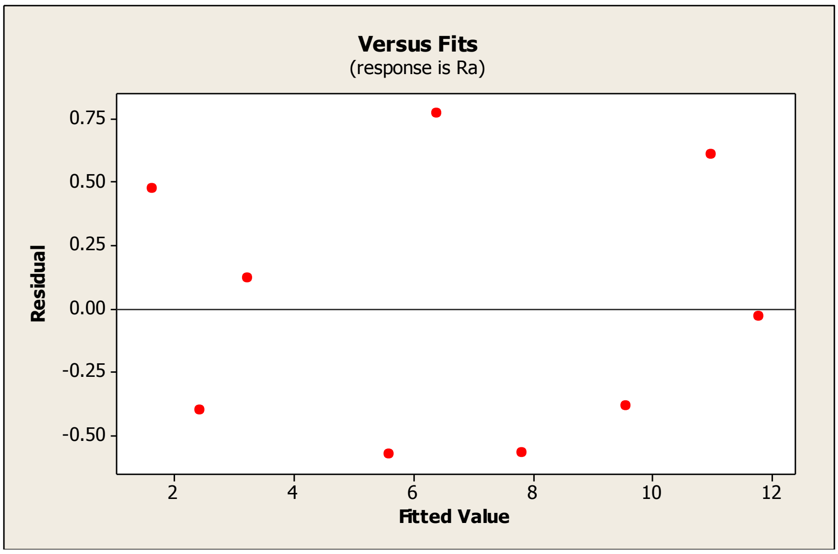

Fig 3: Versus Fits Plot for R_a

Mathematical model for Root Mean Square (RMS) Surface Roughness (R_q) is given by
R_q = -9.36 + 0.00225 v + 48 f – 1.03 d

Table 8: ANOVA for R_q

Source	DOF	SS	MS	F	P	Remarks
Regression	3	146.257	48.752	88.80	0.0000	Significant
Residual Error	5	2.745	0.549			
Total	8	149.002				

S = 0.740934, R^2 = 98.2%, R^2(Adj) = 97.1%

ANOVA for R_q is given in the table 8. The model is significant because of high correlation coefficients (R^2 = 98.2%, R^2 (Adj) = 97.1%). The model for R_q, following a Normal distribution and not representing any particular pattern this can be observed from the Normal probability and versus fits plots for R_q shown in the figures 4 and 5 respectively.

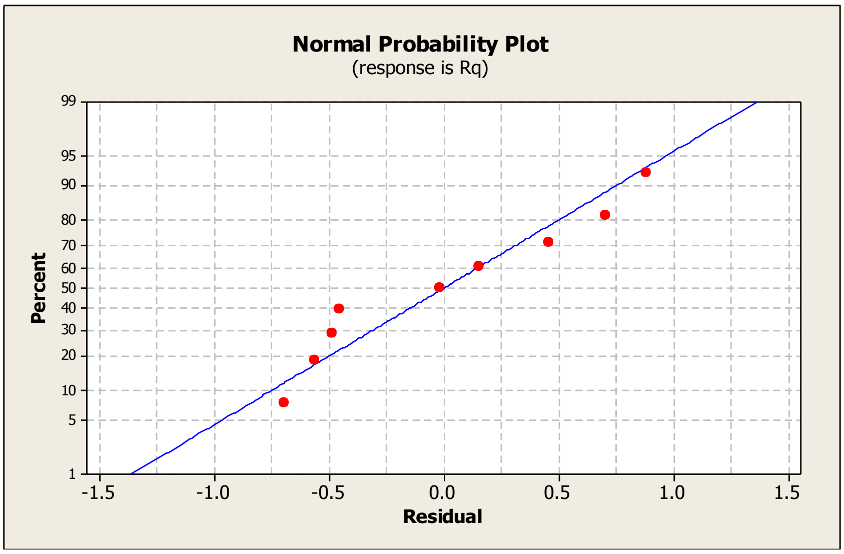

Fig 4: Normal Probability Plot for R_q

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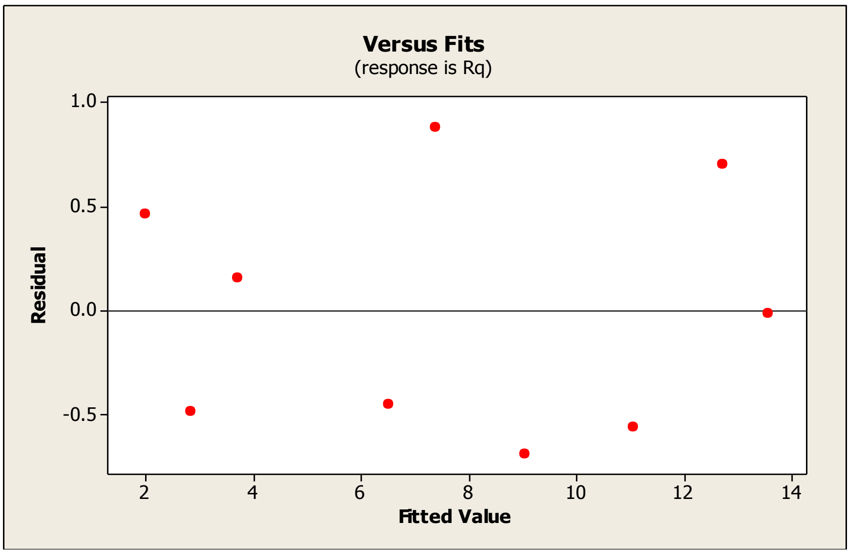

Fig 5: Versus Fits Plot for Rq

The mathematical model for ten point height Surface roughness (R_z) is given by
$R_z = -28.6 + 0.00563\ v + 158\ f - 1.85d$

Table 9: ANOVA for R_z

Source	DOF	SS	MS	F	P	Remarks
Regression	3	1540.04	513.35	98.80	0.0000	Significant
Residual Error	5	25.98	5.20			
Total	8	1566.02				

S = 2.27943, R^2 = 98.3% , R^2(Adj) = 97.3%

ANOVA for R_z is given in the table 9. From the table, it is clear that the model is significant and the model is having high correlation coefficient values (R^2 = 98.3%, R^2(Adj) = 97.3%). Normal probability plot and versus fits plots drawn to R_z (Figures 6 and 7) are showing that the model for R_z is following Normality and Constant variance.

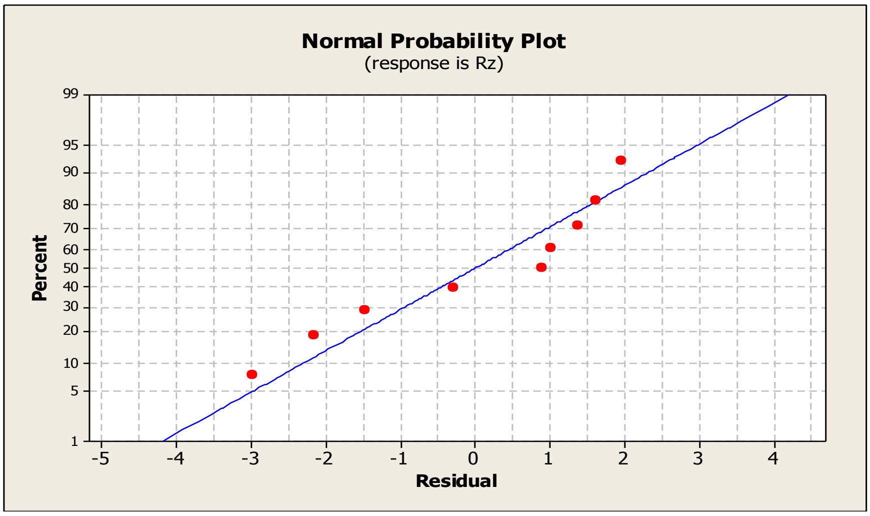

Figure 6: Normal Probability Plot for R_z

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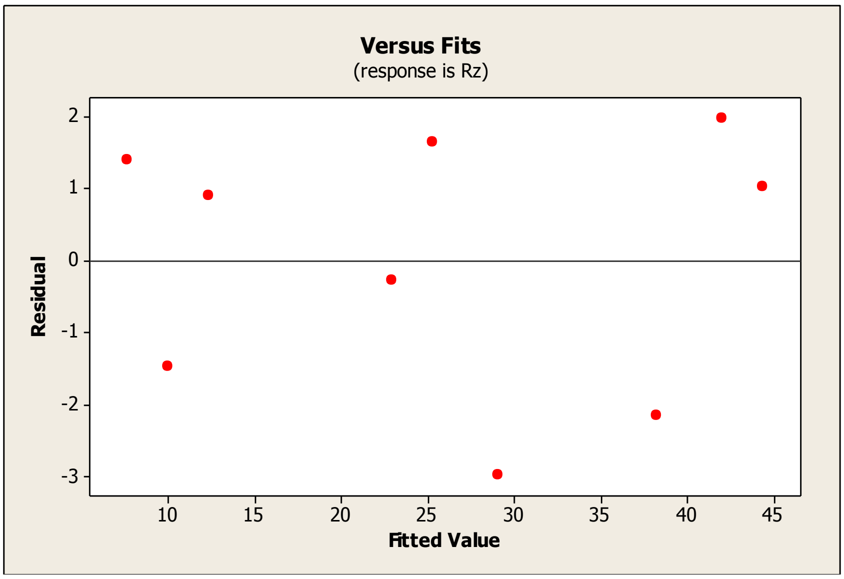

Figure 7: Versus Fits Plot for R_z

From the mathematical models of Surface roughness characteristics R_a, R_q and R_z the predicted values was calculated and given in the table 10. The comparison plots were drawn for experimental (Vs) predicted values of responses and shown in figures 8, 9 and 10. From the comparison plots, it is observed that both experimental and predicted values were very close to each other; hence the models prepared are more accurate.

Table 10. Regression Values of Surface Roughness

S.No.	R_a (µm)	R_q (µm)	R_z (µm)
1	1.64	1.98	7.71
2	5.59	6.52	23.04
3	9.55	11.06	38.38
4	2.43	2.84	10.06
5	6.39	7.39	25.40
6	10.99	12.70	42.12
7	3.23	3.71	12.41
8	7.83	9.03	29.14
9	11.78	13.57	44.47

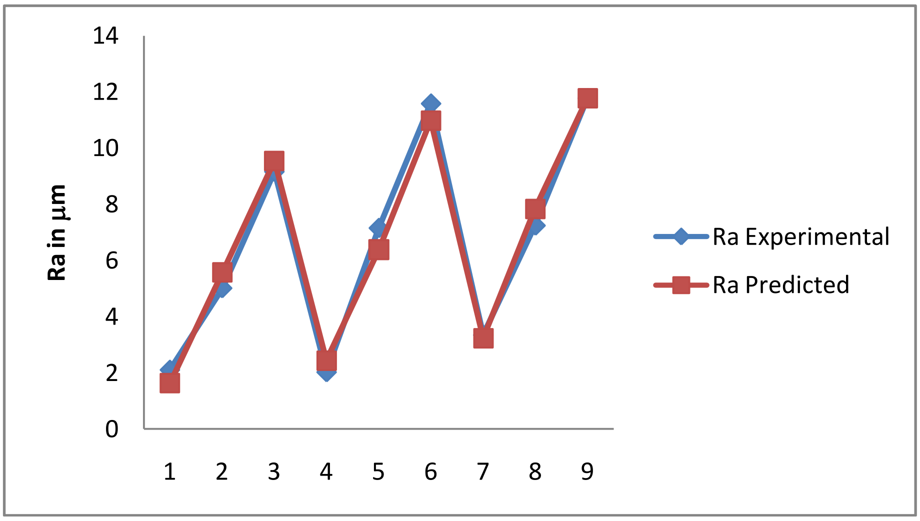

Fig 8: Comparison Graph for Experimental Vs. Regression Values of R_a

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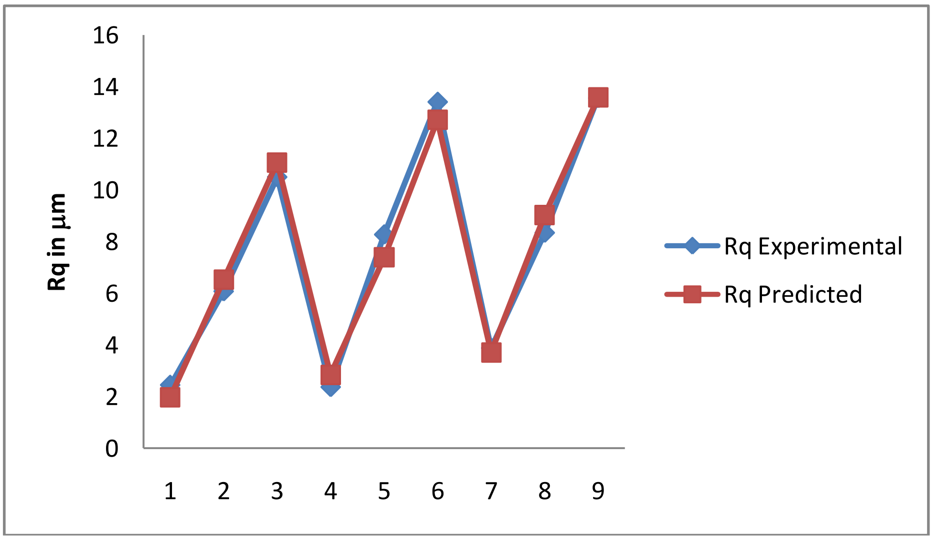

Fig 9: Comparison Graph for Experimental Vs. Regression Values of R_q

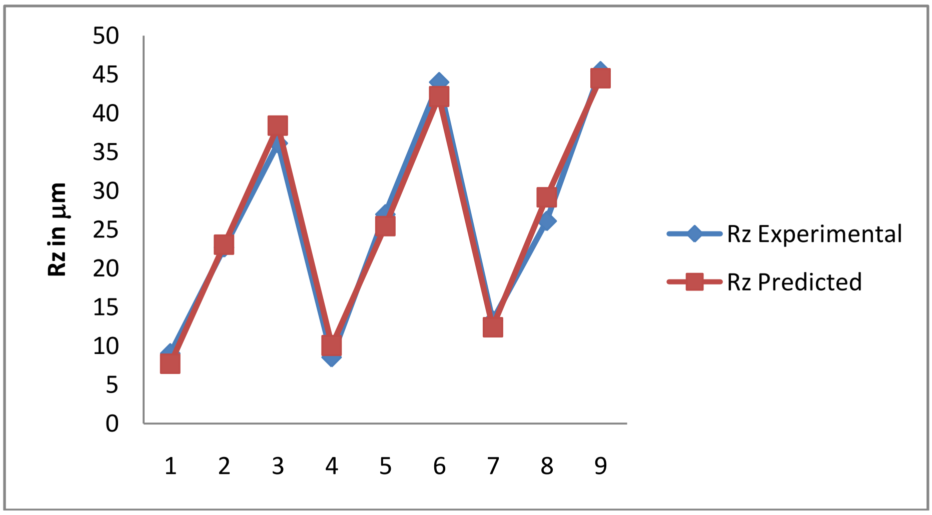

Fig 10: Comparison Graph for Experimental Vs. Regression Values of R_z

COMPARISON OF EXPERIMENTAL, GEOMETRICAL AND REGRESSION VALUES OF R_a

The experimental, geometrical model and predicted values of Surface roughness R_a were given in the table 11. The comparison plot was drawn and shown in the figure 11.

Table 11: Experimental, Geometrical and Regression Values of R_a

S.No.	R_a Experimental	R_a Geometrical	R_a Predicted
1	2.11	3.21	1.64
2	5.023	7.222	5.59
3	9.17	12.84	9.55
4	2.036	3.21	2.43
5	7.16	7.222	6.39
6	11.59	12.84	10.99
7	3.35	3.21	3.23
8	7.25	7.222	7.83
9	11.75	12.84	11.78

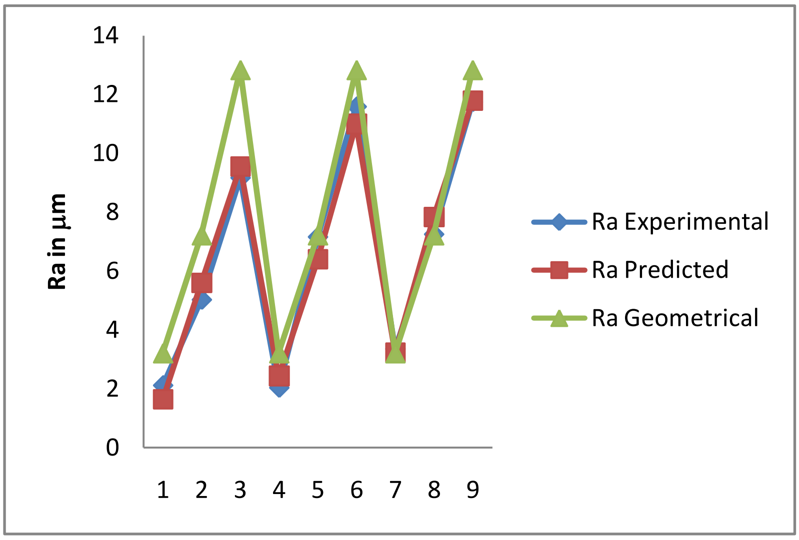

Fig 11: Comparison Graph for Experimental, Geometrical and Regression Values of R_a

CONCLUSIONS

Based on the experimental, geometrical and Regression results obtained by the following conclusions can be drawn

- The mathematical models developed for R_a, R_q and R_z were more significant because of high correlation coefficients and they can be use for better prediction of responses.
  For R_a: R^2 = 98.1%, R^2(Adj) = 96.9%
  R_q: R^2 = 98.2%, R^2(Adj) = 97.1%
  R_z: R^2 = 98.3%, R^2(Adj) = 97.3%
- The Normality and the constant variance assumptions of ANOVA are verified for the models of R_a, R_q and R_z with the help of Normal probability and versus fits plots.
- Regression models are more suitable than geometrical models in order to predict the response values..

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