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Optimization Of Cutting Parameters On Surface Roughness And Material Removal Rate Using Response Surface Methodology In Turning Process Of Al- 7075 With High Speed Steel

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Abstract
This work presents an experimental study to optimize the effect of cutting condition (cutting speed N& feed f& depth of cut) on surface roughness SR (Centre line average roughness (Ra)&Root mean square roughness (Rq)) and material removal rate MRR. Al-7075 workpiece is the experimental material on turning process with HSS. Response surface methodology is the statistical technique used for modelling and analysing. Feed is the most effective parameter on SR. However, MRR has two effective parameters, cutting speed, feed rate.

Key Words: surface Roughness, Turning, Response Surface Methodology, cutting conditions

1-Introduction:

Surface roughness is an effective indicator for product quality and a technical requirement for mechanical products. Accomplishing the looked-for surface quality is of great importance for the efficient performance of a part. Then again, the process dependent nature of the surface roughness formation mechanism along with the several overwhelming factors that influence related phenomena, make nearly impossible an up-front solution. The most communal strategy contains the selection of conventional process constraints, which neither assurances the accomplishment of the looked-for SR nor accomplishes high MRR. Generally, cutting parameters effecting on surface roughness and material removal rate selected based on handbook or experience. However, better results may be achieved by building mathematical model between cutting conditions and roughness and MRR. Many statistical methods used to optimize cutting condition on SR and MRR such as taguchi design, genetic algorithm, neural network, response surface methodology RSM.

RSM consists of a group of mathematical and statistical techniques used in the progress of an acceptable functional relationship between a response of interest, and selected effecting variables. A brief review of literature on optimizing the relation between surface roughness and cutting conditions using statistical method.

P. R. Patel, B. B. Patel, V. A. Patel[1], applied response surface methodology to predict the surface roughness under the turning cutting condition (cutting speed, feed, depth of cut).from the result analysis f is the most effective variable on the SR.

R. Horváth, Á. Drégelyi-Kiss [2], applied response surface methodology to have an empirical relation between surface roughness and cutting conditions. The results showed that N have a small effect on SR. The most effective parameter on surface roughness is feed rate.

Devendra Singh, Devendra Singh, Vimanyu Chadha and Ranganath M Singar[3], applied RSM to study the effect of cutting conditions on SR and optimize by analysis of variance. The results showed that the most effective parameter is nose radius followed by feed rate.

SahooP[4], applied Genetic algorithm and response surface methodology to optimize the turning cutting conditions on surface roughness. The result showed that Increasing N& d decrease the SR. However, increasing feed rate increases surface roughness.

Mahesh kumarsharma, Mahesh kumarsharma, Sanjay singh, Rakesh kumar., [5], applied RSM to study the effect of turning process factors on surface roughness. The results showed that the optimum combination of cutting parameters is f (0.11mm/rev), d (0.3mm) and N (90m/min) on surface roughness.

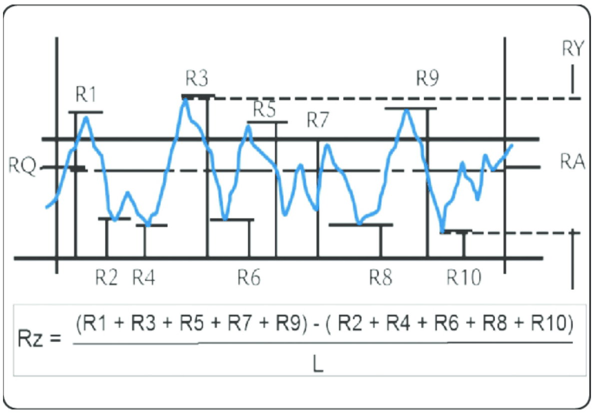
Vishnu Narayan, Aswathy V G [6], studied the effect of turning cutting parameters on surface roughness, surface roundness, material removal rate. From result analysis the f and tool nose radius are the most effective parameters followed by speed & depth of cut.

SHIVAM GOYAL,VARANPAL SINGH KANDRA, and PRAKHAR YADAV [7], investigated the effect of machining factors on SR and MRR when the machining carried out on CNC lathe. The results showed that cutting speed is most significant parameter then feed rate on the Surface roughness. however, the depth of cut is the most significant factors followed by feed on both SR and material removal rate.

Other relevant recent studies include those of Jignesh G.Parmar [8],M. Hanief[9],A. K. Sahoo [10], etc.

1.1Surface roughness:

a surface produced by machining is generally categorized by different types of variables, amplitude variables, spacing variables and hybrid variables. studying the effect of cutting parameters on surface roughness depending on one factor such as centre line average roughness only is not satisfactory. In this work three roughness variable will be consider,(Ra),and (Rq), for the surface produce in turning process of Al-7075.



1.2 Material removal rate:

Material removal rate in metal cutting (turning, milling, and drilling) is a volume of chips removed in 1 minute and it is measured in a three-dimensional quantity. MRR is also an indicator for measuring productivity.

$$MRR = \pi D_{av}\, dfN = \frac{mm^3}{min} \quad (1)$$

$$D_{av} = \frac{D_o + D_f}{2} \quad (2)$$

$$d = \frac{D_o - D_f}{2} \quad (3)$$

1.3 Response surface methodology:

Response surface methodology consist of statistical and mathematical models which are useful for modelling and analysing the selected response or responses depending on the selected several parameters. Response surface methodology used as an optimization tool of response by optimizing involved input parameters. The steps involved in RSM:

1. Designing a set of experiments
2. Construct the mathematical model of response
3. Analyse the mathematical model and select the optimum value of involved parameters.
4. Representing the effect of input parameters on the selected response

Many software's are developed for helping researchers in their work with all optimization techniques. In this work MINITAB-16 are used.

2-Experimentaldetails:

The work is carried out with the following plan

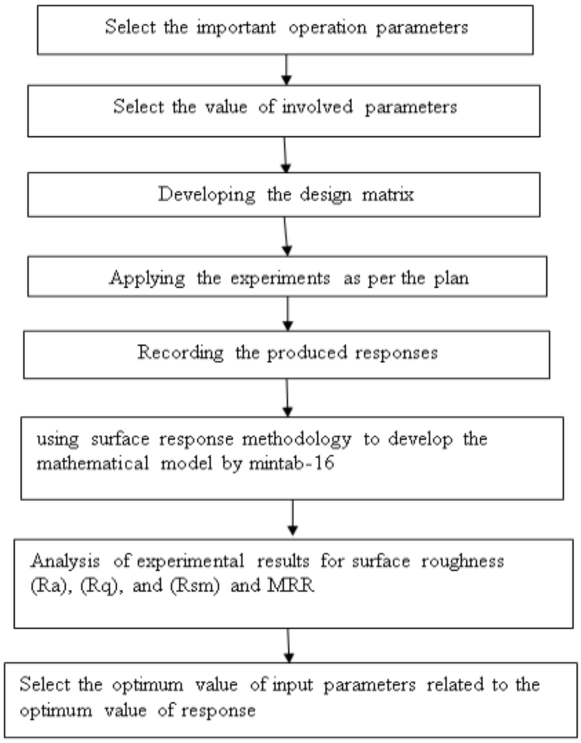


Figure 1 Experimental plan

2.1 Workpiece material and cutting tool:

Alloy 7075 have high strength so is used in highly stressed structural parts industries. Airplane fittings, gears, shafts, meter shafts, missile parts, fuse parts, regulating valve parts are such application use AL7075.

Table 1: Chemical composition of Al7075.

Chemical Composition	AL	Cr	Cu	fe	Mg	Zn	Si	Mn	Ti	Others
Wt%	89.79	0.08	1.35	0.3	2.21	5.67	0.4	0.08	0.06	0.06

Table 2: Mechanical properties of AL7075

Hardness, Vickers	Ultimate Tensile Strength	Tensile Yield Strength	Fatigue Strength	Fracture Toughness	Machinability
175	572Mpa	503Mpa	159Mpa	25MPa-m½	70%

Cutting tool used for turning is high speed steel (HSS). To study the effect of cutting parameters (N, d, f) on SR and Material removal rate. Turning experiments done with AL7075 rounded bar with diameter of 42 mm and length of 20cm.

Table 3: parameters ranges

parameter	Level 1	Level 2	Level 3
Cutting speed (rpm)	265	475	850
Feed rate (mm/rev)	0.06	0.10	0.15
Depth of cut (mm)	0.4	0.8	1.0

2.3Response variables selected:

The response variables selected to complete this study are

A. Centre line average roughness (Ra):
B. Root mean square roughness (Rq):
C. Material removal rate

4 -Results and discussion:

Experimental measurements showed in the next table:

Table 4: actual measurement

std	N(rpm)	f(mm/rev)	d (mm)	R_a	R_q	MRR
1	265	0.06	0.8	0.843	1.141	27.592
2	265	0.15	0.8	1.286	1.117	27.592
3	850	0.06	0.8	0.957	1.149	27.592
4	850	0.15	0.8	1.360	0.976	29.625
5	265	0.10	0.4	1.214	1.470	23.090
6	265	0.10	1.0	1.201	0.959	9.236
7	850	0.10	0.4	1.188	1.208	15.393
8	850	0.10	1.0	1.164	1.185	15.393
9	475	0.06	0.4	0.895	1.585	74.064
10	475	0.06	1.0	0.951	1.176	49.376
11	475	0.15	0.4	1.489	1.165	49.376
12	475	0.15	1.0	1.476	1.685	30.202
13	475	0.10	0.8	1.188	1.513	30.202
14	475	0.10	0.8	1.208	0.986	16.555
15	475	0.10	0.8	1.155	0.968	16.555

4.1 Result analysis:

The second order response surface equations have been fitted using minitab-16

$$Ra = 1.21356 + 0.01410*N + 0.24780*f - 0.00004*d - 0.04946*N^2 - 0.05881*f^2 + 0.05590*d^2 - 0.01437*Nf + 0.00434*Nd - 0.02521*fd \quad (4)$$

$$Rq = 1.17518 + 0.00901*N + 0.30614*f - 0.02851*d + 0.00180*N^2 - 0.07562*f^2 + 0.03960*d^2 + 0.02342*Nf + 0.01373*Nd - 0.04400*fd \quad (5)$$

$$MRR = 33.8318 + 17.8807*N + 11.7366*f + 0.0470*d + 3.0213*N^2 - 2.5169*f^2 - 3.1335*d^2 + 8.3623*Nf - 0.0001*Nd + 0.8463*fd \quad (6)$$

Table 5: coefficient of input parameters

Sl. no	Coefficient	Ra	Rq	MRR
1	C_0	1.21356	1.17518	33.8318
2	C_1	0.01410	0.00901	17.8807
3	C_2	0.24780	0.30614	11.7366
4	C_3	-0.00004	-0.02851	0.0470
5	C_{11}	-0.04946	0.00180	3.0213
6	C_{22}	-0.05881	0.07562	-2.5169
7	C_{33}	0.05590	0.03960	-3.1335
8	C_{12}	-0.01437	0.02342	8.3623
9	C_{13}	0.00434	0.01373	-0.0001
10	C_{23}	-0.02521	-0.04400	0.8463

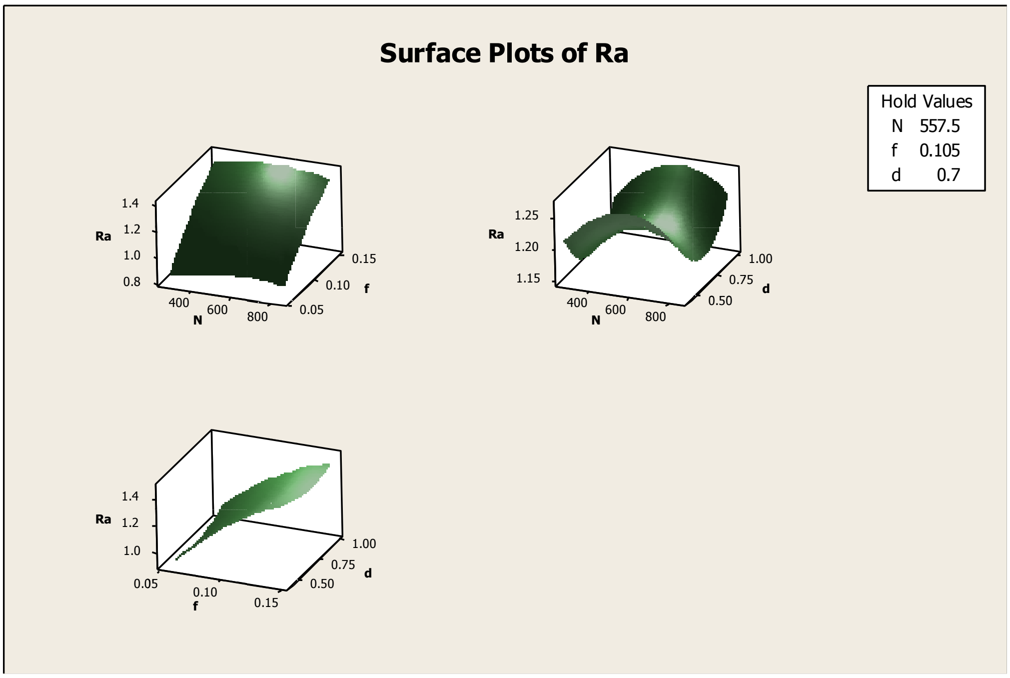


Figure 2: surface plot of Ra

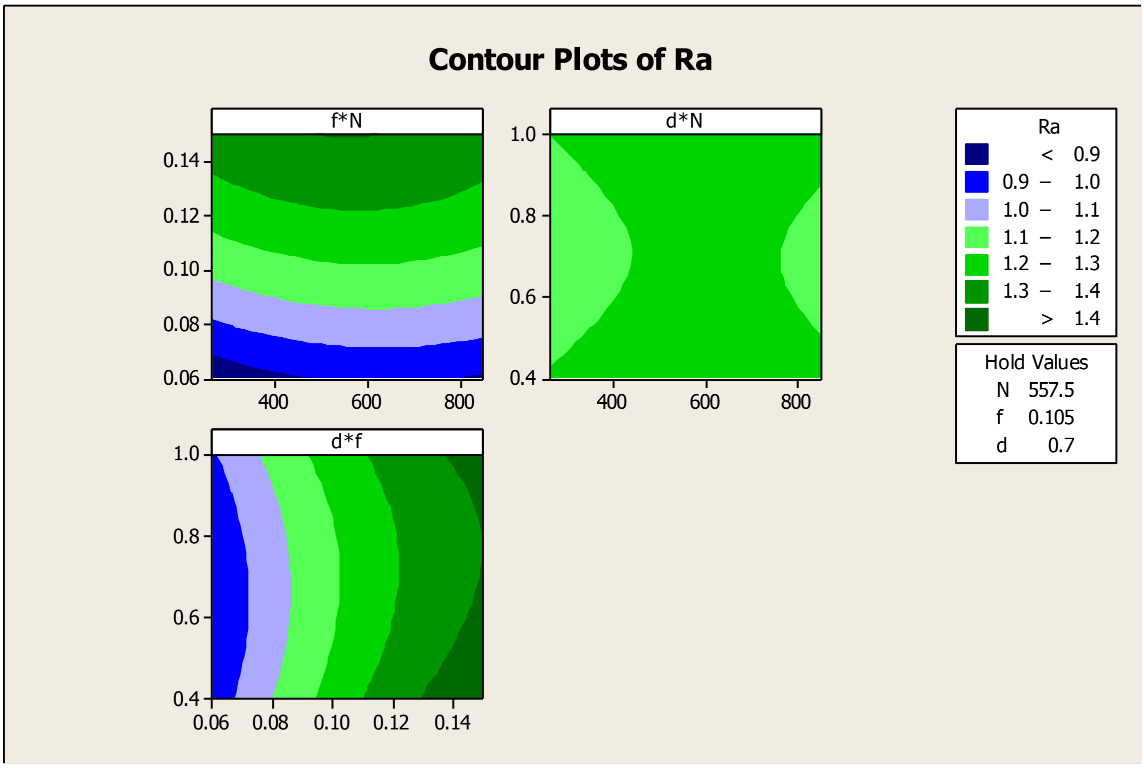


Figure 3: contour plot of Ra

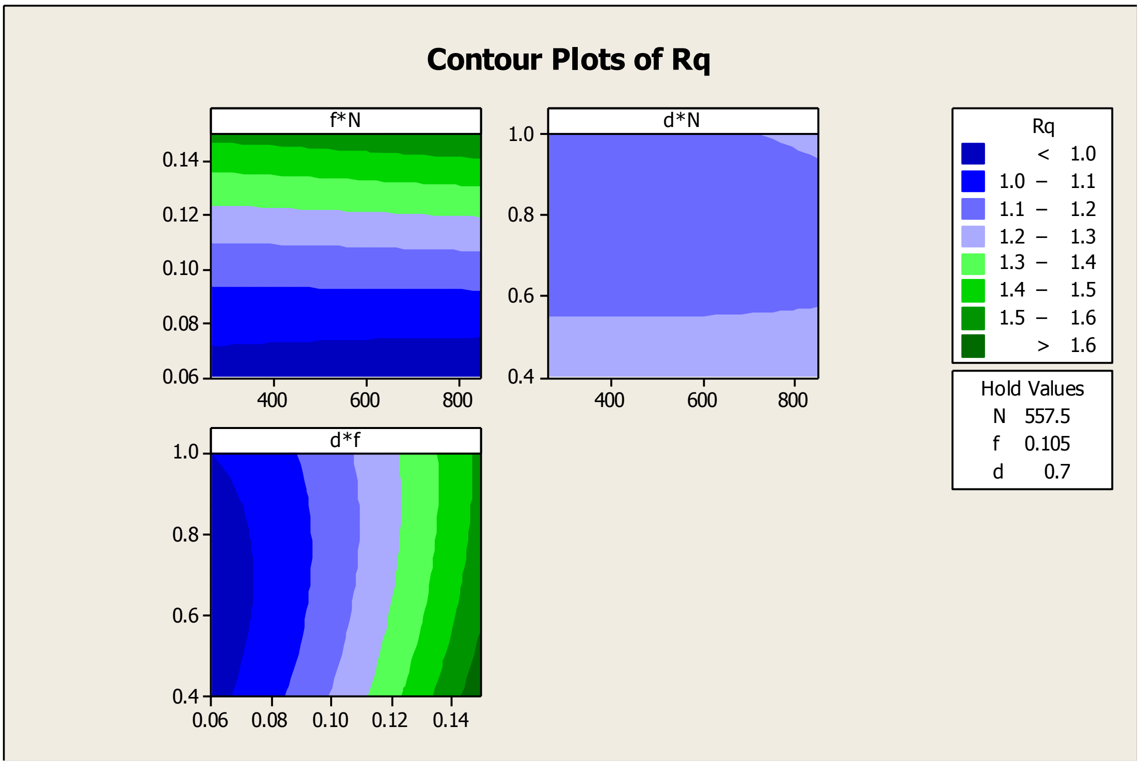


Figure 4: contour plot of Rq

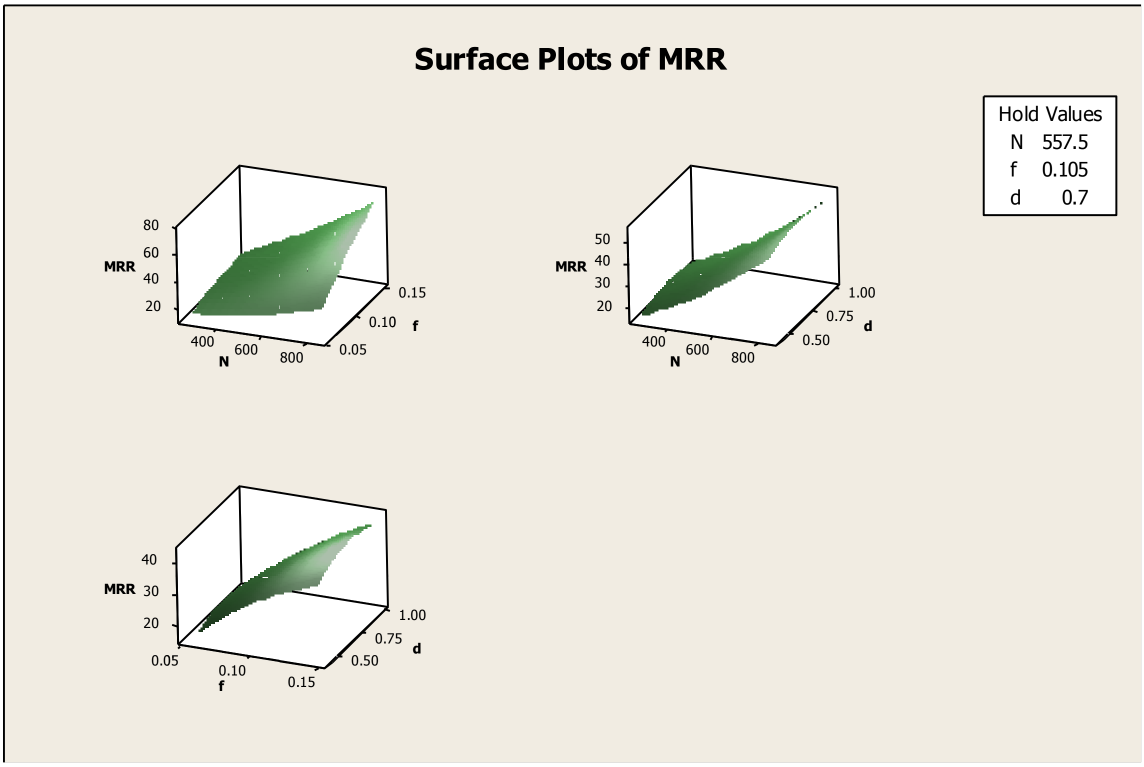


Figure 5: surface plot of MRR

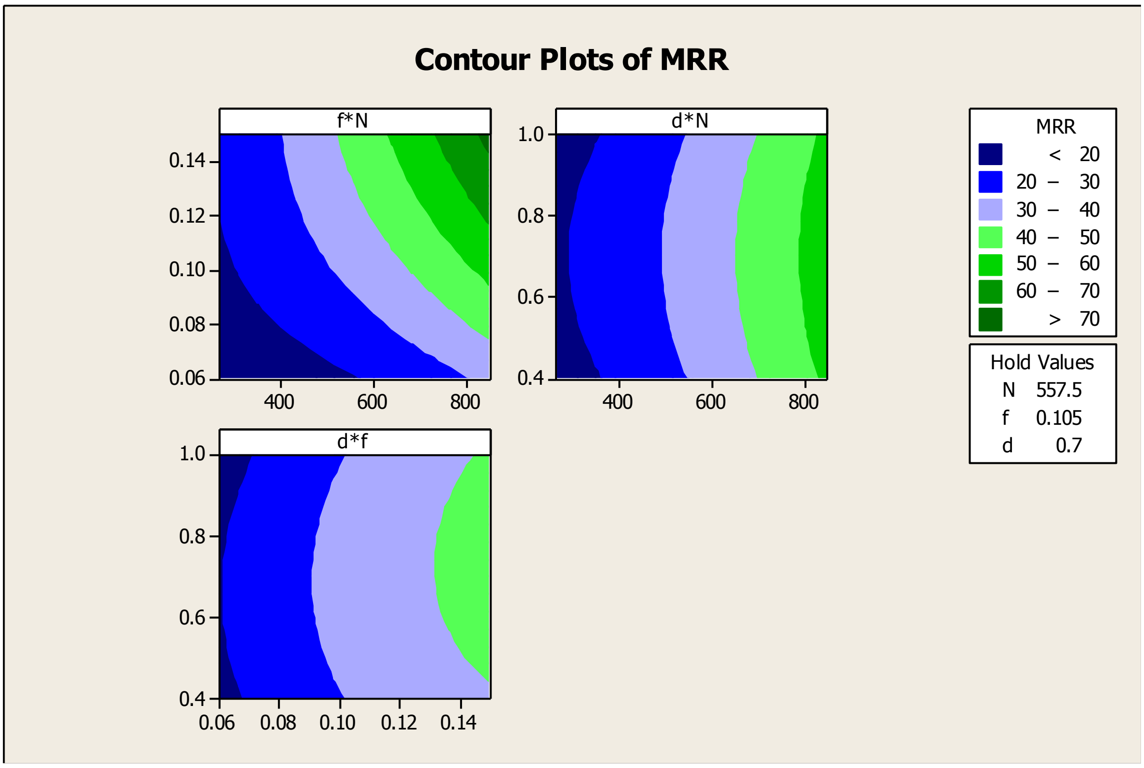


Figure 6: contour plot of MRR

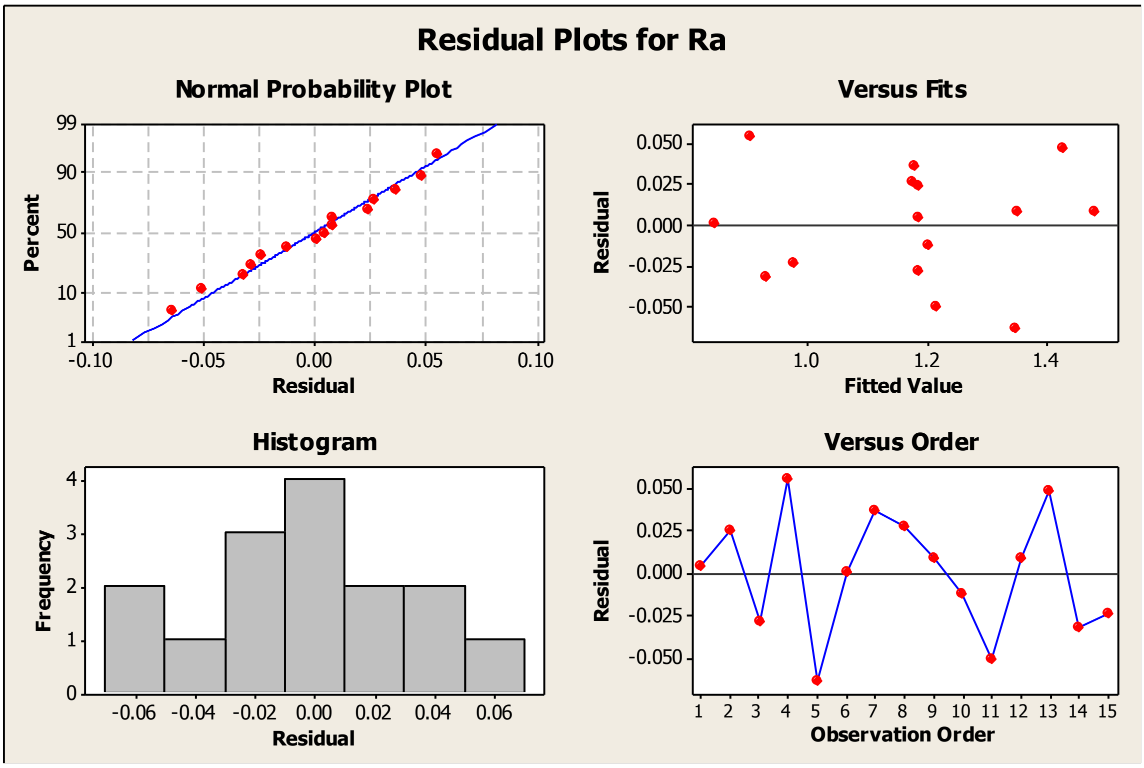


Figure 7: residual plots for Ra

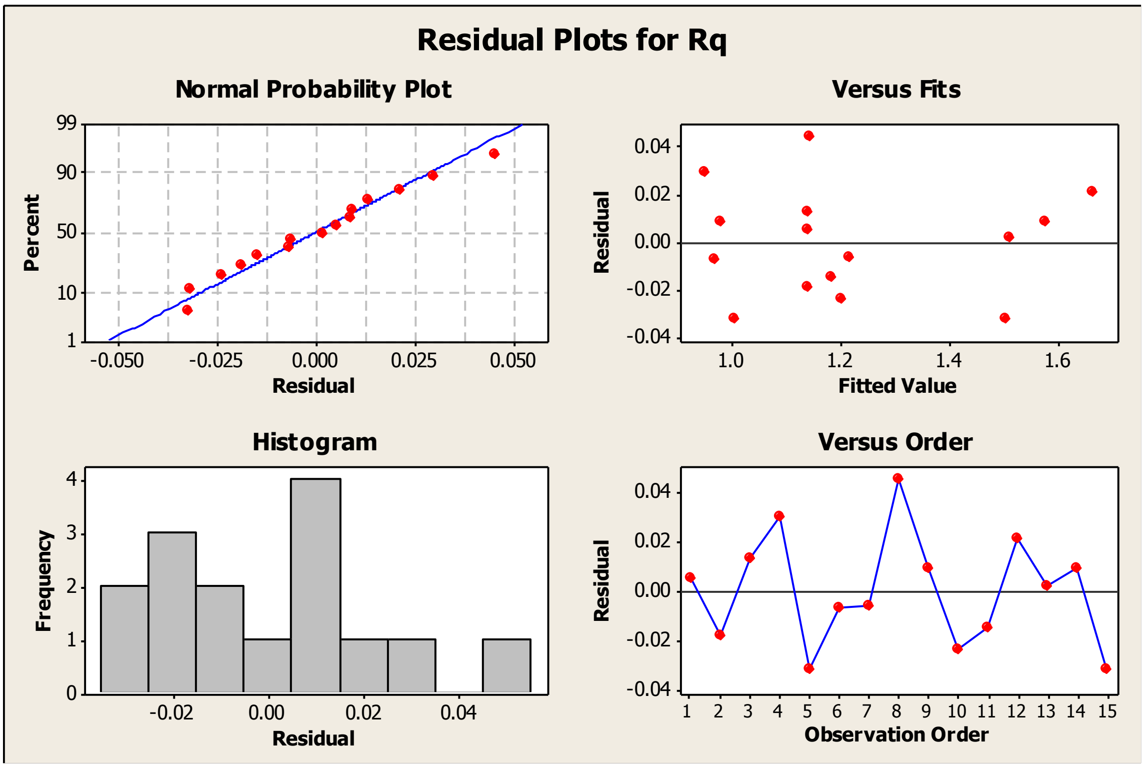


Figure 8: residual plots for Rq

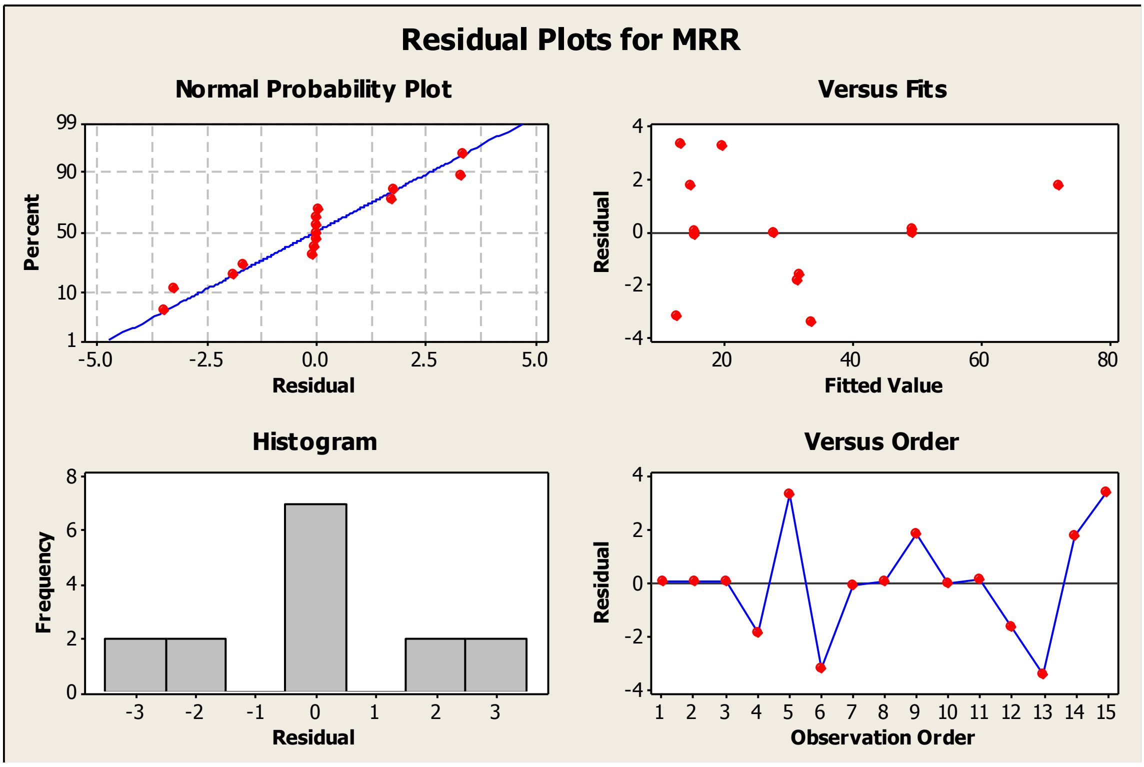


Figure 9: residual plots for MR

5-Conclusion:

Response surface methodology is applied successfully in analysing the effect of cutting parameters (cutting speed, feed, depth of cut) on selected surface roughness variables (Centre line average roughness &Root mean square roughness) and material removal rate. Result analysis showed that:

i. Feed rate is the most effective parameter on surface roughness.
ii. The most significant conditions on material removal rate are cutting speed and feed rate.

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