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EXPERIMENTAL INVESTIGATIONS TO DETERMINE OPTIMAL CUTTING PARAMETERS IN GRINDING OPERATIONS BY DESIGN OF EXPERIMENTS

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ABSTRACT:-In this thesis different experiments will be conducted by grinding aluminium 7475 pieces varying the cutting parameters table feed, depth of cut and RPM for better hardness, material removal rates. The optimal parameters will be determined using Design of Experiments considering L9 orthogonal array in Minitab software. Finally we are going to test the work pieces under the hardness test for every piece to get the better result and even corrosion test is done to find out the corrosion formation on every piece including the raw material.

INTRODUCTION

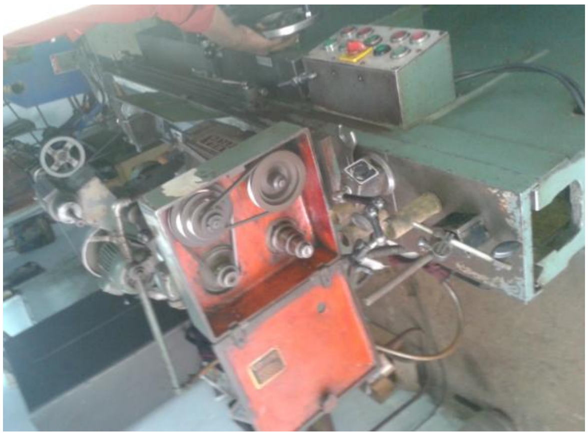
THE GRINDING PROCESS
Grinding is the procedure of eliminating metal by the request of abrasives which are bonded to form a rotating wheel. When the moving abrasive particles interact with the work component, they will act as small cutting tools, every particle cutting as a tiny chip from the work component. The grinding machine provisions and rotates the grinding abrasive wheel and often supports & positions the work component in proper relation to the wheel.

TYPES OF GRINDING
There are four major grinding process
1. Cylindrical grinding process
2. Internal grinding process
3. Centerless grinding process
4. Surface grinding process

OBJECTIVE OF THE PRESENT WORK
The main objective of the work here is to find the surface roughness and the material removal rates while grinding the AL 7475 work piece by varying the parameters using taguchi method.
Here we are going to consider the L9 orthogonal array, the parameters considered here for the experimentation are feed 11mm/min, 19mm/min and 28mm/min, the spindle speed are 1100rpm, 1200rpm and 1400 rpm, and finally the depth of cut considered here is 0.01mm, 0.05mm and 0.1mm.
Different experiments are conducted by taking above values of parameters as per L9 orthogonal array. The optimal parameters are chosen for better surface roughness and material removal rates and this optimization is carried out using Taguchi Method in Minitab software.

EXPERIMENTAL INVESTIGATION
The material Aluminium 7475 is selected as work piece material having diameter 68.5 mm and length180 mm round bar.

Hydraulic Cylindrical Grinding Machine



Switches for operation

Machine Specifications

DESIGN OF EXPERIMENTS

In order to identify the process parameters affecting the selected machine quality characteristics of turning, the following process parameters are selected for the present work: Spindle Speed (A), feed (B) and depth of cut (C). The selection of parameters of interest and their ranges is based on literature review and some preliminary experiments conducted .The machining is done on 3 round pieces, on each 3 experiments are conducted by varying the process parameters.

The levels of input parameters are shown in below table.

FACTORS	PROCESS PARAMETERS	LE VEL1	LEVEL2	LEVEL3
A	SPINDLE SPEED(rpm)	1100	1200	1400
B	FEED RATE (mm/min)	11	19	28
C	DEPTH OF CUT(mm)	0.1	0.05	0.01

Table – Levels of Process Parameters considered for experimentation L9 orthogonal array

EXPERIMENTATION PHOTOS

Fig - Work Piece Preparation

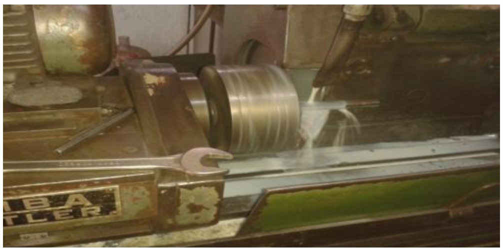


Fig – Grinding of Work Piece

Fig - Application of coolant while grinding

Fig – Grinding of Work Piece

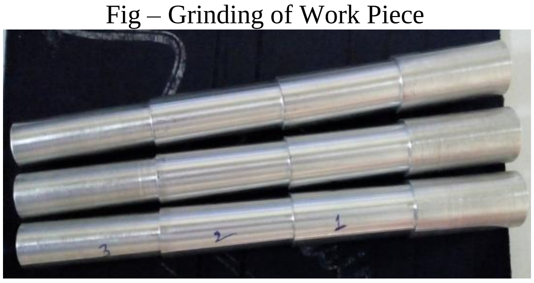


Fig - Prepared Work pieces after cylindrical Grinding Process

SURFACE ROUGHNESS

After completing the experimental trails using L9 orthogonal array, the surface roughness values are measured using surface roughness tester of model Surf test 211/212 and the results are tabulated.

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Surface Roughness (R_a) μm
1	1100	11	0.1	0.34
2	1100	19	0.05	0.52
3	1100	28	0.01	0.61
4	1200	11	0.05	0.47
5	1200	19	0.01	0.29
6	1200	28	0.1	0.43
7	1400	11	0.01	0.25
8	1400	19	0.05	0.34
9	1400	28	0.1	0.72

Table - Measured Surface Roughness Values

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	Weight (before grinding) Wb (gms)	Weight (after grinding) Wa (gms)	Time (sec.)
1	1100	11	0.1	127.373	127.012	43
2	1100	19	0.05	127.82	127.563	56
3	1100	28	0.01	128.093	127.895	71
4	1200	11	0.05	126.811	126.653	34
5	1200	19	0.01	127.257	126.958	57
6	1200	28	0.1	126.407	126.103	44
7	1400	11	0.01	128.376	128.131	39
8	1400	19	0.05	128.182	128.006	32
9	1400	28	0.1	128.34	128.014	41

Table - Measured values of weights before and after grinding and time taken for machining for each job

CALCULATIONS OF MRR

1. MRR= (Wb-Wa)/Tm =127.373 -127.012/ 43 =0.00839534 gm/sec
2. MRR=127.82–127.563/ 56 = 0.00458928gm/sec
3. MRR=128.093–127.895/ 71 = 0.00278873gm/sec
4. MRR=126.811–126.653/ 34 = 0.00464705gm/sec
5. MRR=127.257–126.958/ 57 =0.00524561 gm/sec
6. MRR=126.407–126.103 / 44 = 0.00690909gm/sec
7. MRR=128.376–128.131/ 39 = 0.00628205gm/sec
8. MRR=128.182–128.006/ 32 = 0.0055gm/sec
9. MRR=128.34–128.014/ 41 = 0.00795121gm/sec

JOB NO.	SPINDLE SPEED (rpm)	FEED RATE (mm/min)	DEPTH OF CUT (mm)	MRR (gm/sec)
1	1100	11	0.1	0.00839534
2	1100	19	0.05	0.00458928
3	1100	28	0.01	0.00278873
4	1200	11	0.05	0.00464705
5	1200	19	0.01	0.00524561
6	1200	28	0.1	0.00690909
7	1400	11	0.01	0.00628205
8	1400	19	0.05	0.0055
9	1400	28	0.1	0.00795121

Table - Calculated values of MRR for each job

OPTIMIZATION OF PARAMETERS FOR LESSER SURFACE ROUGHNESS VALUE
S/N Graph

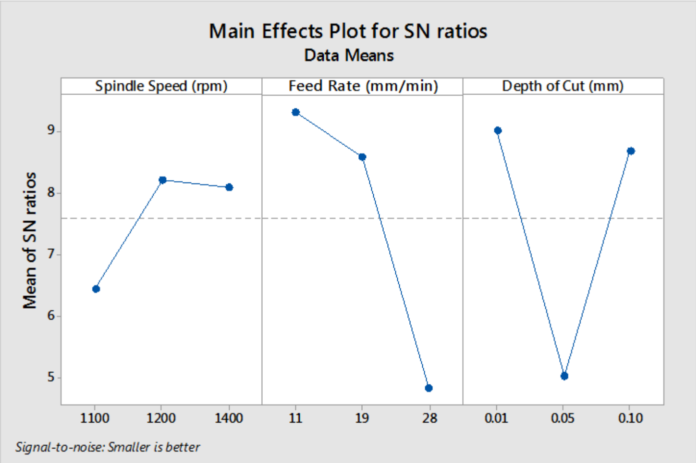


Fig - Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

Taguchi Analysis: Surface Roughness versus Spindle Speed, Feed Rate (m, Depth of Cut

Response Table for Signal to Noise Ratios
Smaller is better

Level	Spindle Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)
1	6.448	9.323	9.029
2	8.214	8.601	5.030
3	8.088	4.826	8.690
Delta	1.766	4.497	3.998
Rank	3	1	2

Results

Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The Surface Roughness is considered as the quality characteristic with the concept of "the smaller-the-better".

ANALYSIS AND DISCUSSION

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Spindle Speed:-The effect of parameter "Spindle Speed" on surface roughness values is shown above figure for S/N ratio. The optimum Spindle Speed is 1200rpm.

Feed Rate:-The effect of parameter "Feed Rate" on surface roughness values is shown above figure for S/N ratio. The optimum Feed Rate is 11mm/min.

Depth of cut:-The effect of parameter "Depth of cut" on surface roughness values is shown above figure for S/N ratio. The optimum Depth of cut is 0.01mm

OPTIMIZATION OF PARAMETERS FOR HIGHER MATERIAL REMOVAL RATE
Graph

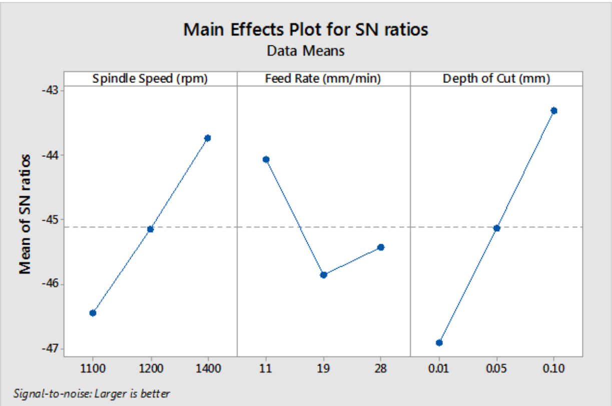


Fig - Effect of machining parameters on MRR for S/N ratio for Larger is better

Taguchi Analysis: MRR (gm/sec) versus Spindle Speed (r, Feed Rate (mm/mi, Depth of Cut (mm)
Response Table for Signal to Noise Ratios
Larger is better

Level	Spindle Speed (rpm)	Feed-Rate (mm/min)	Depth of Cut (mm)
1	-46.46	-44.07	-46.91
2	-45.16	-45.85	-45.14
3	-43.74	-45.43	-43.31
Delta	2.72	1.78	3.60
Rank	2	3	1

Results
Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The MRR is considered as the quality characteristic with the concept of "larger-the-better".

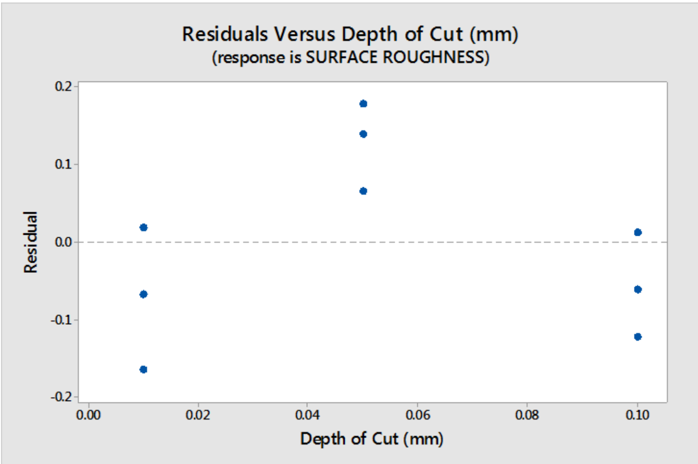
Analysis and Discussion
Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Spindle Speed:-The effect of parameter "Spindle Speed" on surface roughness values is shown above figure for S/N ratio. The optimum Spindle Speed on is 1400rpm.

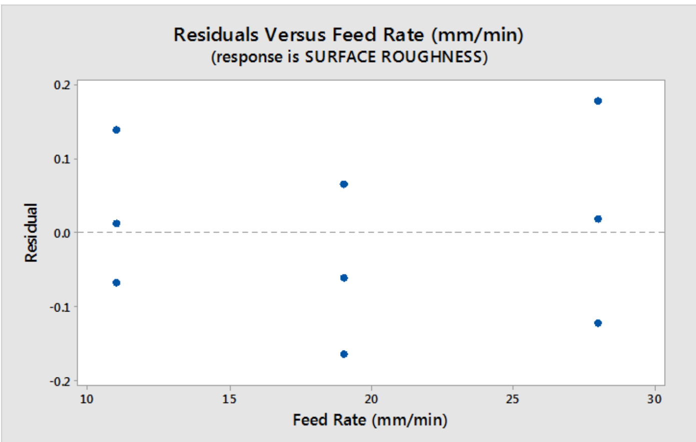
Feed Rate:-The effect of parameter "Feed Rate" on surface roughness values is shown above figure for S/N ratio. The optimum Feed Rate is 11mm/min.

Depth of cut:-The effect of parameter "Depth of cut" on surface roughness values is shown above figure for S/N ratio. The optimum Depth of cut is 0.1mm.

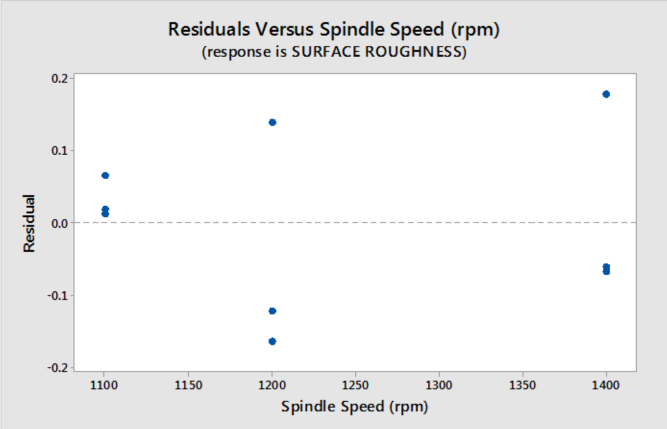
OPTIMIZATION USING REGRESSION ANALYSIS
Graphs



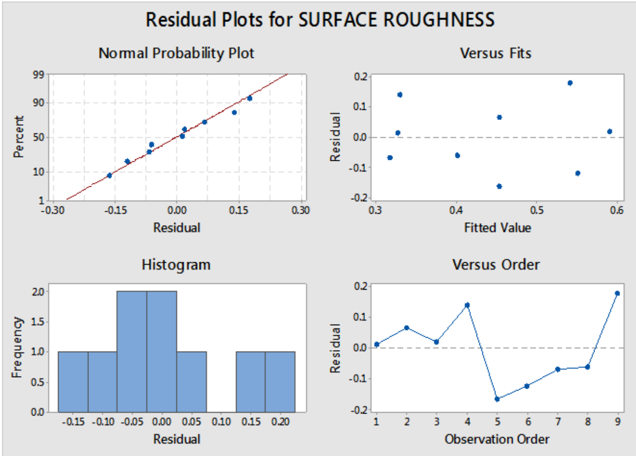
Graph - Residual Vs Depth of cut (Response – Surface Roughness)



Graph - Residual Vs Feed Rate (Response – Surface Roughness)



Graph - Residual Vs Spindle Speed (Response – Surface Roughness)



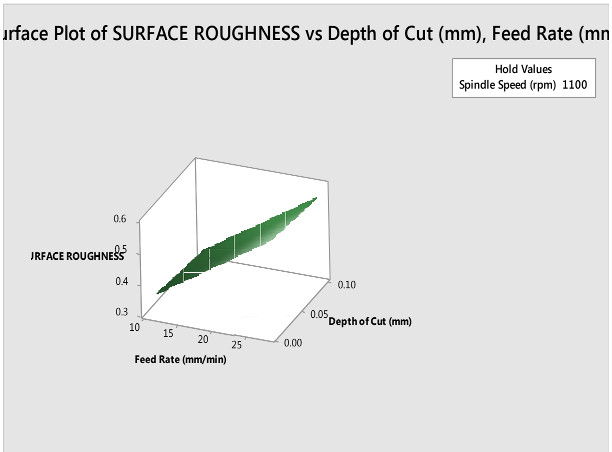
Graph - Residual Plots for Surface Roughness)

The residual plots indicate that the deterministic portion (predictor variables) of the model Spindle Speed, Cut Feed and Step Over are not capturing some explanatory information that is "leaking" into the residuals. The graph could represent several ways in which the model is not explaining all that is possible. Possibilities include:

- A missing variable
- A missing higher-order term of a variable in the model to explain the curvature
- A missing interaction between terms already in the model

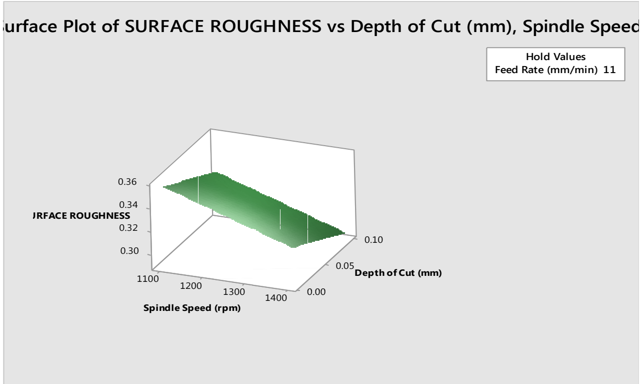
Result and discussions

The 3D response surface plot is a graphical representation of the regression equation. It is plotted to understand the interaction of the variables and locate the optimal level of each variable for maximal response.



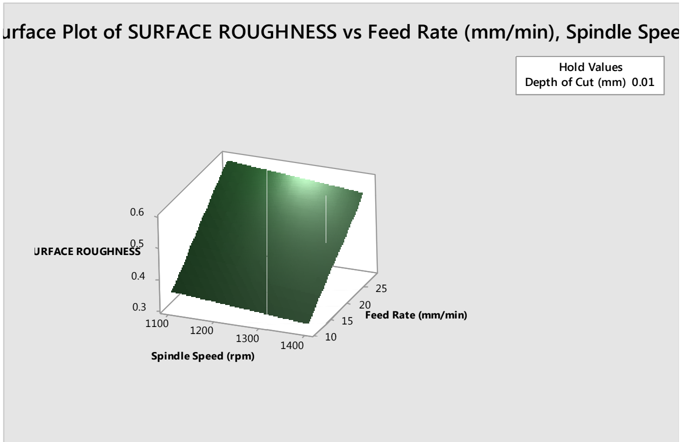
Graph – Surface Plot of Surface Roughness vs Depth of cut, Feed Rate

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Depth of cut at 0.1mm.



Graph - Surface Plot of Surface Roughness vs Spindle Speed, Depth of cut

By observing above graph, to minimize surface roughness, the Spindle Speed should be set at 1400rpm and Depth of cut at 0.1mm.



Graph - Surface Plot of Surface Roughness vs Cut Feed, Spindle Speed

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Spindle Speed to 1400rpm

Analysis of Variance of MRR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0.000010	0.000003	1.15	0.414
Spindle Speed (rpm)	1	0.000003	0.000003	0.94	0.376
Feed Rate (mm/min)	1	0.000000	0.000000	0.14	0.728
Depth of Cut (mm)	1	0.000007	0.000007	2.37	0.184
Error	5	0.000015	0.000003		
Total	8	0.000025			

By observing P – value from above table, it can be found that the most important parameter for MRR is Depth of cut.

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0017228	40.84%	5.34%	0.00%

The optimization carried out is good as the R-Sq is 40.84%.

The goodness-of-fit of the model was checked by the determination coefficient (R2 – 40.84%). The adjusted determination coefficient (adj. R2 =5.34%) was also satisfactory for confirming the significance of the model.

Coefficients

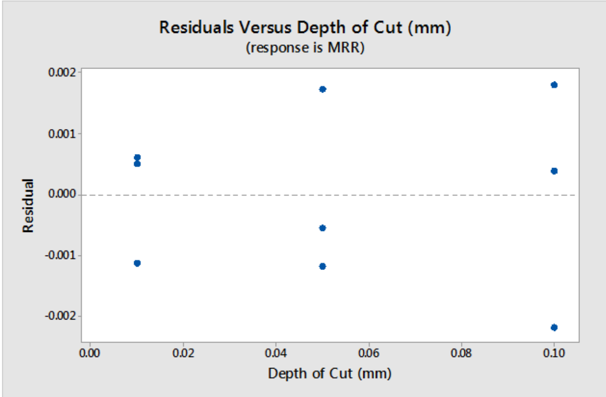
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-0.00039	0.00599	-0.07	0.950	
Spindle Speed (rpm)	0.000004	0.000005	0.97	0.376	1.00
Feed Rate (mm/min)	-0.000030	0.000083	-0.37	0.728	1.00
Depth of Cut (mm)	0.0240	0.0156	1.54	0.184	1.00

The probability (p) values were used as a tool to check the significance of each of the coefficients. A smaller p-value denotes greater significance of the corresponding coefficient.

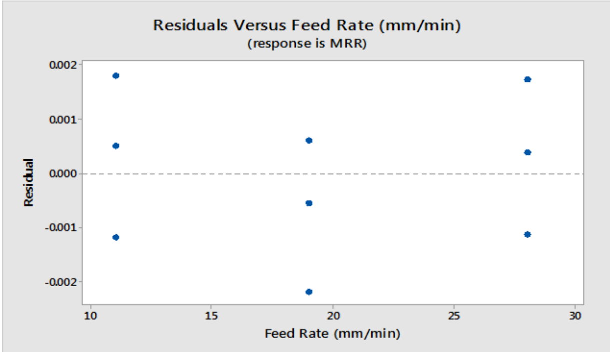
Regression Equation

MRR = -0.00039 + 0.000004 Spindle Speed (rpm) - 0.000030 Feed Rate (mm/min)
+ 0.0240 Depth of Cut (mm)

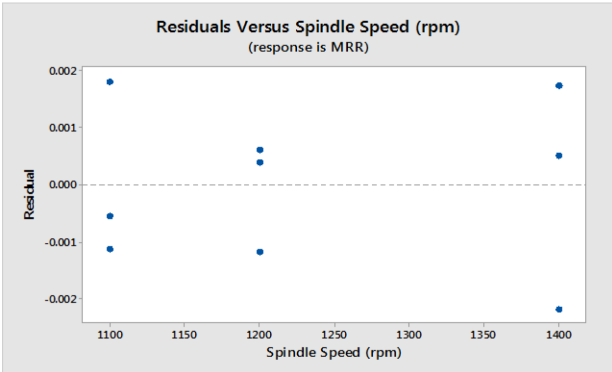
Graphs



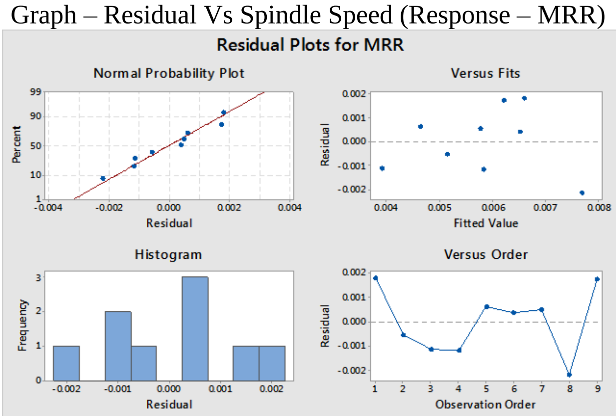
Graph - Residual Vs Depth of cut (Response – MRR)



Graph – Residual Vs Feed Rate (Response – MRR)



Graph – Residual Vs Spindle Speed (Response – MRR)



Graph - Residual Plots for MRR

The residual plots indicate that the deterministic portion (predictor variables) of the model Spindle Speed, Cut Feed and Step Over are not capturing some explanatory information that is "leaking" into the residuals. The graph could represent several ways in which the model is not explaining all that is possible. Possibilities include:

- A missing variable
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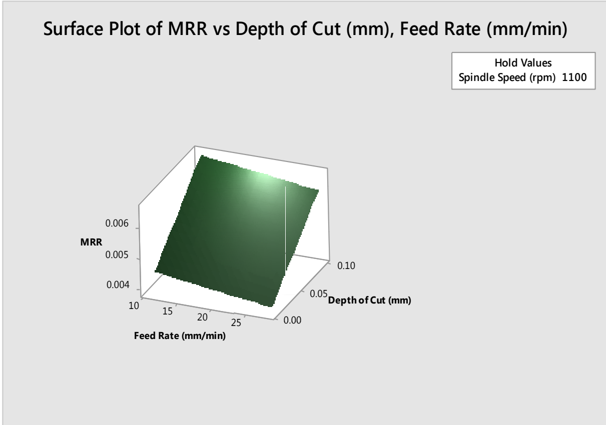
Result and Discussion

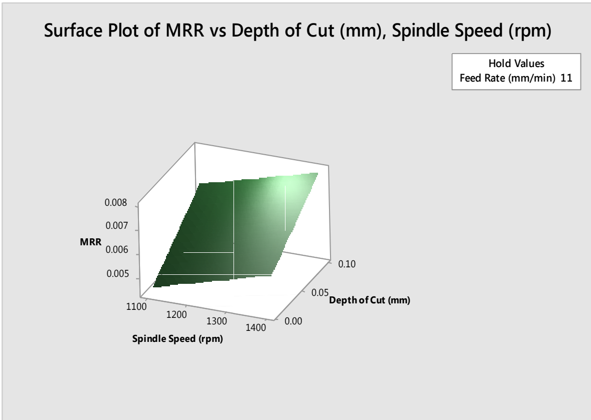
The 3D response surface plot is a graphical representation of the regression equation.

It is plotted to understand the interaction of the variables and locate the optimal level of each variable for maximal response.



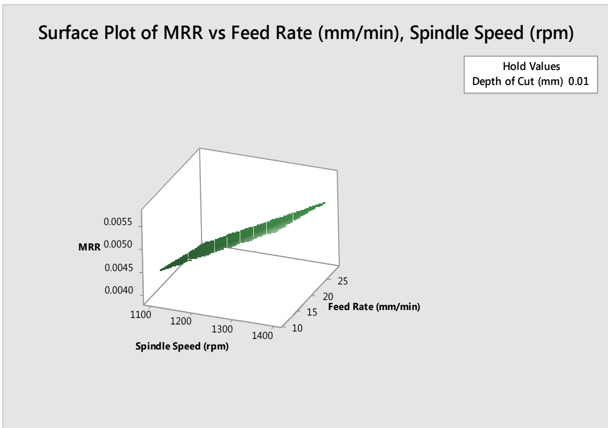
Graph - Surface Plot of MRR vs Depth of cut, Feed Rate

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Depth of cut at 0.1mm.



Graph - Surface Plot of MRR vs Spindle Speed, Depth of cut

By observing above graph, to minimize surface roughness, the Spindle Speed should be set at 1400rpm and Depth of cut at 0.1mm.



Graph - Surface Plot of MRR vs Feed Rate, Spindle Speed

By observing above graph, to minimize surface roughness, the Feed Rate should be set at 11mm/min and Spindle Speed to 1400rpm.

CONCLUSION

In this thesis, different experiments are performed on Aluminium alloy 7475 work piece by varying various parameters to determine Material Removal rates and Surface Roughness. The parameters considered for experimentation are feed 11mm/min, 19mm/min and 28mm/min, the Grinder speeds 1100rpm, 1200rpm and 1400rpm and the depth of cut 0.01mm, 0.05mm and 0.1mm.

Optimization is done using L9 orthogonal array by Taguchi technique and regression analysis to determine better parameters to obtain maximum material removal rates and lesser surface roughness values.

From the Taguchi Method, the following conclusions can be made:

- For better surface finish, the optimized process parameters are the Feed Rate –11mm/min, Depth of Cut - 0.01mm and Spindle Speed - 1200rpm.
- For better MRR, the optimized process parameters are the Feed Rate –11mm/min, Depth of Cut –0.1mm and Spindle Speed - 1400rpm.

From the Regression analysis, the following conclusions can be made:

- For better surface finish, the optimized process parameters are the Feed Rate –11mm/min and Depth of Cut - 0.1mm and Spindle Speed - 1400rpm.
- For better MRR, the optimized process parameters are the Feed Rate –11mm/min and Depth of Cut –0.1mm and Spindle Speed - 1400rpm.

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