ANALYSIS AND OPTIMISATION OF SURFACE ROUGHNESS IN AL2014 USING END MILLING UNDER WET AND DRY CONDITIONS

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ABSTRACT

The purpose of this research was to investigate the effect of the main factors on the surface roughness in Al 2014 face milling. The results of the research could be applied in the manufacture of automotive components and mold industry. The study was conducted by using computer numerical controlled (CNC) milling machine with 63 millimeter diameters fine type carbide tool with twin cutting edge. For this experiment we used Taguchi designs. The result revealed that the factors affected the surface roughness were the depth of cut while the speed unaffected the surface roughness. Low Surface roughness value and Flatness Error were obtained during the dry condition with high speed face milling operation. Flatness error mainly affected with feed factor percentage of 41% verified through CMM.

KEYWORD: *Surface Roughness,Face Milling,AL2014,Feed Factor,CMM.*

1. INTRODUCTION

1.1 End Milling

The End Milling may be considered as the combination of peripheral and face milling operations. The cutter has teeth both on the end face and on the periphery. The cutting characteristics may be of peripheral or face milling type according to the particular cutter surface used. When the end cutting edges are only used to remove the metal the direction of rotation and the direction of the helix of the cutter should be same. The end milling is the operation of producing a flat surface which may be vertical, horizontal or at an angle in reference to the table surface.

2. MATERIAL PROPERTIES

2.1MATERIAL- AL2014

Table 2.1 Chemical properties of AL2014

Element	Content (%)
Aluminium / Aluminum, Al	93.5
Copper, Cu	4.4
Silicon, Si	0.8
Magnesium, Mg	0.5
Cromium, Cr	0.1 (Max)
Manganese, Mn	0.6

Table 2.2 Physical properties of AL2014

Properties	**Metric**	**Imperial**
Density	2.8 g/cm^3	0.1018 lb/in^3
Melting point	510°C	950°F

Table 2.3 thermal properties of AL2014

Properties		**Conditions**	
		T (ºC)	**Treatment**
Thermal expansion	23 (10^{-6}/ºC)	20-100	-
Thermal conductivity	192 (W/mK)	25	O

Table 2.4 mechanical properties of AL2014

Properties	**Metric**	**Imperial**
Elastic modulus	70-80 GPa	10152-11603 ksi
Poisson's ratio	0.33	0.33

3.TAGUCHI OPTIMIZATION

3.1TAGUCHI APPROACH The experimental results are then transformed into a signal – to – noise (S/N) ratio to measure the quality. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic. They are

1) Smaller-The-Better,
2) Larger-The-Better,
3) Nominal is Best.

SMALLER IS BETTER

$$S/N = -10*\log(S\ (Y^2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

LARGER IS BETTER

$$S/N = -10*\log(S(1/Y^2)/n)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

NOMINAL IS BEST

$$S/N = -10*\log (s^2)$$

Where s = standard deviation of the responses for all noise factors for the given factor level combination

3.2 DESIGN OF EXPERIMENT

TABLE:3.1 Process parameters and their levels

Levels	Process parameters		
	speed	**Feed**	**DOC**
1	2400	1000	0.2
2	3000	1200	0.4
3	3600	1500	0.6

3.3 AN ORTHOGONAL ARRAY L_9 FORMATION

Table :5.2 An Orthogonal Array L_9 Formation

TRIAL NO.	DESIGNATION	speed	feed	DOC
1	$A_1B_1C_1$	2400	1000	0.2
2	$A_1B_2C_2$	2400	1200	0.4
3	$A_1B_3C_3$	2400	1500	0.6
4	$A_2B_1C_2$	3000	1000	0.4
5	$A_2B_2C_3$	3000	1200	0.6
6	$A_2B_3C_1$	3000	1500	0.2
7	$A_3B_1C_3$	3600	1000	0.6
8	$A_3B_2C_1$	3600	1200	0.2

4.EXPERIMENTAL RESULT

4.1 EXPERIMENTAL DATA

Table 4.1AL2014 out put resultface milling with and with out cooling

Trial	Parameter	Speed	Feed	DOC	MT Min	RA-(wc)-µs	RA(woc)µs	Flatness (WC)-mm	Flatness (WOC) mm
1	$A_1B_1C_1$	1000	1200	0.25	4.36	0.939	0.554	0.027	0.020
2	$A_1B_2C_2$	1000	1400	0.50	4.21	0.963	0.472	0.044	0.028
3	$A_1B_3C_3$	1000	1600	0.75	4.13	0.817	0.587	0.060	0.030
4	$A_2B_1C_2$	1500	1200	0.50	4.31	0.975	0.425	0.021	0.017
5	$A_2B_2C_3$	1500	1400	0.75	4.13	0.627	0.479	0.028	0.043
6	$A_2B_3C_1$	1500	1600	0.25	4.20	0.721	0.425	0.037	0.037
7	$A_3B_1C_3$	2000	1200	0.75	4.09	1.024	0.453	0.008	0.026
8	$A_3B_2C_1$	2000	1400	0.25	4.26	1.032	0.331	0.036	0.032
9	$A_3B_3C_2$	2000	1600	0.50	4.21	0.895	0.410	0.018	0.017

Wc-without coolant, woc-without coolant

4.2 MACHINING TIME

Table-4.2 (ANALYSIS OF RESULT-MT)

Trial	Designation	Speed	Feed	DOC	MT	SNRA1
1	$A_1B_1C_1$	1000	1200	0.25	4.36	-12.7897
2	$A_1B_2C_2$	1000	1400	0.50	4.21	-12.4856
3	$A_1B_3C_3$	1000	1600	0.75	4.13	-12.3190
4	$A_2B_1C_2$	1500	1200	0.50	4.31	-12.6895
5	$A_2B_2C_3$	1500	1400	0.75	4.13	-12.3190
6	$A_2B_3C_1$	1500	1600	0.25	4.20	-12.4650
7	$A_3B_1C_3$	2000	1200	0.75	4.09	-12.2345
8	$A_3B_2C_1$	2000	1400	0.25	4.26	-12.5882
9	$A_3B_3C_2$	2000	1600	0.50	4.21	-12.4856

Table-4.3Response Table for Signal to Noise Ratios-Smaller is better(MT)

Level	Speed	Feed	doc
1	-12.53	-12.57	-12.61
2	-12.49	-12.46	-12.55
3	-12.44	-12.42	-12.29
Delta	0.10	0.15	0.32
Rank	3	2	1

Table -4.4 Response Table for Means (MT)

Level	Speed	Feed	doc
1	4.233	4.253	4.273
2	4.213	4.200	4.243
3	4.187	4.180	4.117
Delta	0.047	0.073	0.157
Rank	3	2	1

4.3 Main Effects Plot for Means

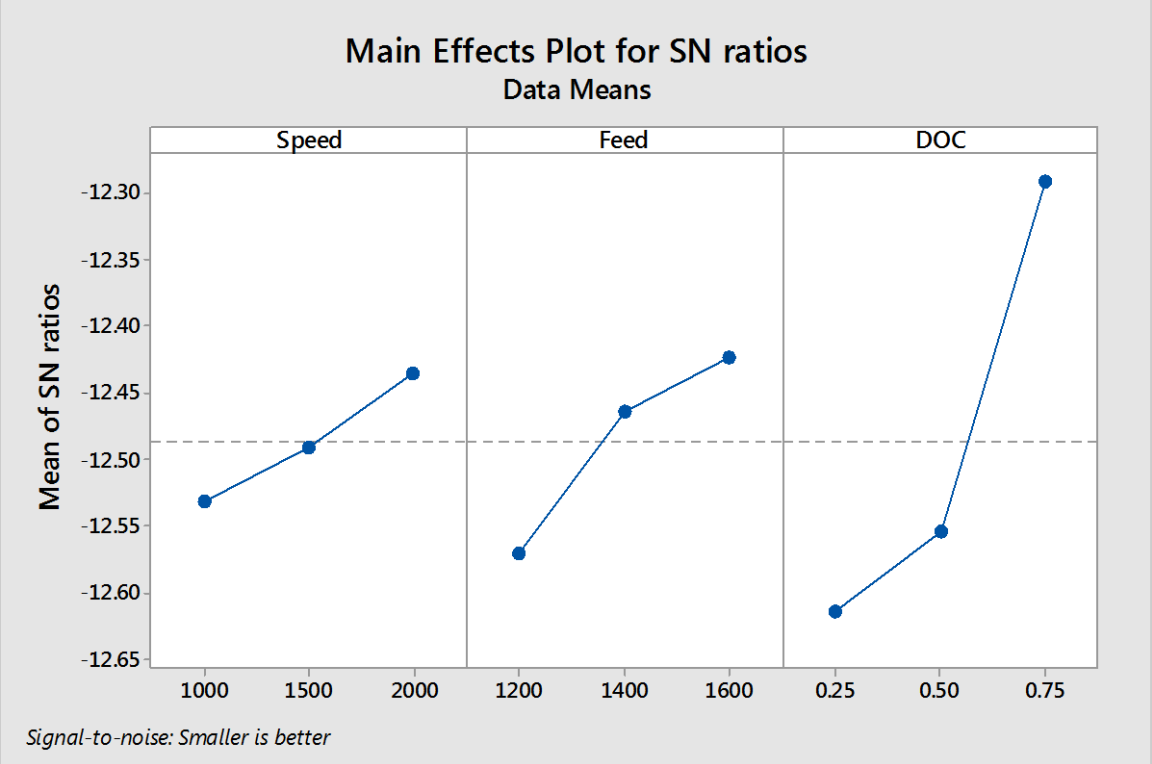
Factor	Type	Levels	Values
SPEED	fixed	3	1000,1500,2000
FEED	fixed	3	1200,1400,1600
DOC	fixed	3	0.25,0.50,0.75

Table4.5 Analysis of Variance for MT, using Adjusted SS for Tests

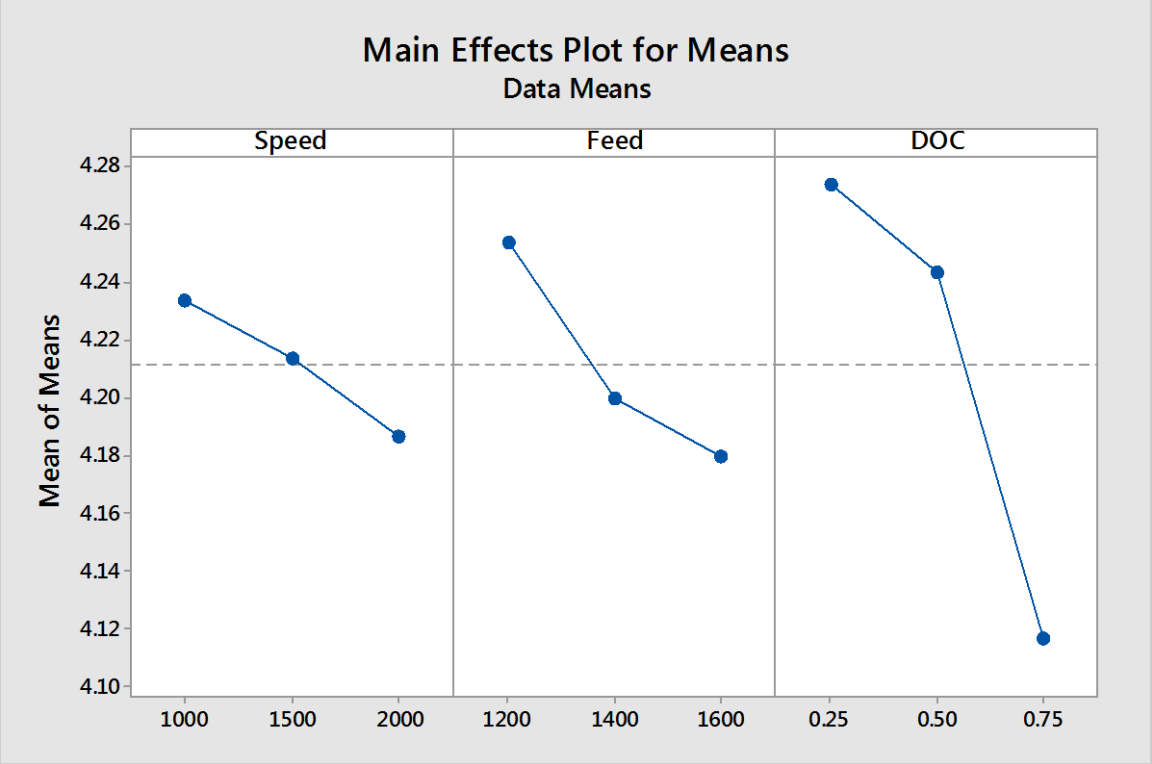
Source	DF	Seq SS	Adj SS	F	P	% Contribution
SPEED	2	0.003289	0.001644	0.37	0.730	6
FEED	2	0.008622	0.004311	0.97	0.508	14
DOC	2	0.041489	0.020744	4.67	0.176	66
Error	2	0.008889	0.004444			14
Total	8	0.062289				100

MT = 4.2111 + 0.0222 Speed_1000 + 0.0022 Speed_1500 - 0.0244 Speed_2000 + 0.0422 Feed_1200
- 0.0111 Feed_1400 - 0.0311 Feed_1600 + 0.0622 DOC_0.25 + 0.0322 DOC_0.50
- 0.0944 DOC_0.75

4.3.1 Main Effects Plot for SN ratios



4.3.2 Main Effects Plot for Means



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4.4 Taguchi Analysis: MT versus Speed, Feed, DOC

Response Table for Signal to Noise Ratios
Smaller is better

Level	Speed	Feed	DOC
1	-12.53	-12.57	-12.61
2	-12.49	-12.46	-12.55
3	-12.44	-12.42	-12.29
Delta	0.10	0.15	0.32
Rank	3	2	1

Response Table for Means

Level	Speed	Feed	DOC
1	4.233	4.253	4.273
2	4.213	4.200	4.243
3	4.187	4.180	4.117
Delta	0.047	0.073	0.157
Rank	3	2	1

4.5 General Linear Model: MT versus Speed, Feed, DOC

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Speed	Fixed	3	1000, 1500, 2000
Feed	Fixed	3	1200, 1400, 1600
DOC	Fixed	3	0.25, 0.50, 0.75

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	0.003289	0.001644	0.37	0.730
Feed	2	0.008622	0.004311	0.97	0.508
DOC	2	0.041489	0.020744	4.67	0.176
Error	2	0.008889	0.004444		
Total	8	0.062289			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0666667	85.73%	42.92%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF

Constant 4.2111 0.0222 189.50 0.000
Speed
1000 0.0222 0.0314 0.71 0.553 1.33
1500 0.0022 0.0314 0.07 0.950 1.33
Feed
1200 0.0422 0.0314 1.34 0.311 1.33
1400 -0.0111 0.0314 -0.35 0.757 1.33
DOC
0.25 0.0622 0.0314 1.98 0.186 1.33
0.50 0.0322 0.0314 1.03 0.413 1.33

Regression Equation

MT = 4.2111 + 0.0222 Speed_1000 + 0.0022 Speed_1500 - 0.0244 Speed_2000 + 0.0422 Feed_1200
- 0.0111 Feed_1400 - 0.0311 Feed_1600 + 0.0622 DOC_0.25 + 0.0322 DOC_0.50
- 0.0944 DOC_0.75

4.6 SURFACE ROUGHNESS (ANALYSIS OF RESULT)

Table-4.6 ANALYSIS OF RESULT-Ra

TRIAL NO.	**DESIGNATION**	Speed	Feed	DOC	Ra	SNRA1
1	$A_1B_1C_1$	1000	1200	0.25	0.554	5.12980
2	$A_1B_2C_2$	1000	1400	0.50	0.472	6.52116
3	$A_1B_3C_3$	1000	1600	0.75	0.587	4.62724
4	$A_2B_1C_2$	1500	1200	0.50	0.425	7.43222
5	$A_2B_2C_3$	1500	1400	0.75	0.479	6.39329
6	$A_2B_3C_1$	1500	1600	0.25	0.425	7.43222
7	$A_3B_1C_3$	2000	1200	0.75	0.453	6.87804
8	$A_3B_2C_1$	2000	1400	0.25	0.331	9.60344
9	$A_3B_3C_2$	2000	1600	0.50	0.410	7.74432

Table-4.7Response Table for Signal to Noise Ratios-Smaller is better-Ra

Level	speed	Feed	doc
1	5.426	6.480	7.388
2	7.086	7.506	7.233
3	8.075	6.601	5.966
Delta	2.649	1.026	1.422
Rank	1	3	2

Table -4.8 Response Table for Means-Ra

Level	speed	Feed	doc
1	0.5377	0.4773	0.4367
2	0.4430	0.4273	0.4357
3	0.3980	0.4740	0.5063
Delta	0.1397	0.0500	0.0707
Rank	1	3	2

4.9 General Linear Model: Ra versus SPEED, FEED, DOC

Factor	Type	Levels	Values
SPEED	fixed	3	1000,1500,2000
FEED	fixed	3	1200,1400,1600
DOC	fixed	3	0.25,0.50,0.75

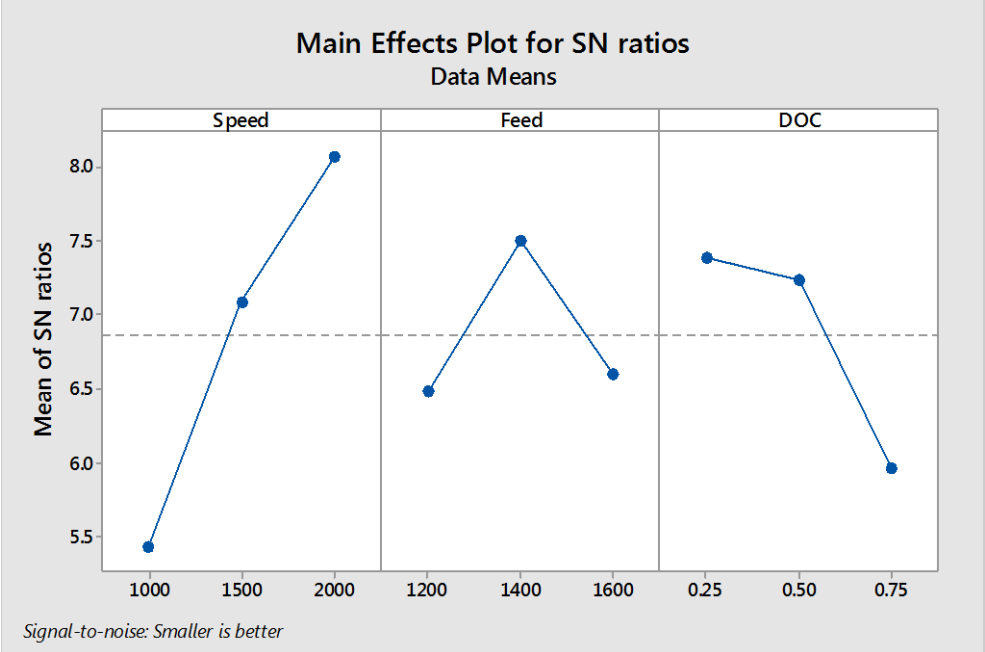
Table-4.9 Analysis of Variance for Ra, using Adjusted SS for Tests-Ra

Source	DF	Seq SS	Adj SS	F	P	% OF Contribution
SPEED	2	0.030494	0.015247	14.67	0.064	64
FEED	2	0.004689	0.002344	2.26	0.307	10
DOC	2	0.009848	0.004924	4.74	0.174	9
Error	2	0.002078	0.001039			7
Total	8	0.047108				100

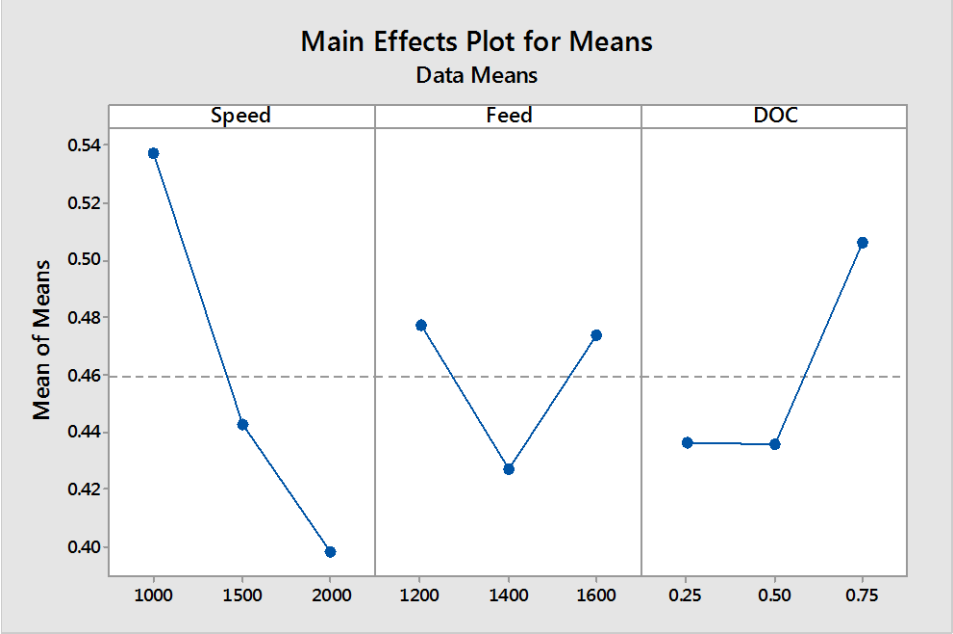
Regression Equation

RA NON COOLANT = 0.4596 + 0.0781 Speed_1000 - 0.0166 Speed_1500 - 0.0616 Speed_2000
+ 0.0178 Feed_1200 - 0.0322 Feed_1400 + 0.0144 Feed_1600 - 0.0229 DOC_0.25
- 0.0239 DOC_0.50 + 0.0468 DOC_0.75

4.9.1 Main Effects Plot for SN ratios



4.9.2 Main Effects Plot for Means



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Taguchi Analysis: RA NON COOLANT versus Speed, Feed, DOC

Response Table for Signal to Noise Ratios
Smaller is better

Level	Speed	Feed	DOC
1	5.426	6.480	7.388
2	7.086	7.506	7.233
3	8.075	6.601	5.966
Delta	2.649	1.026	1.422
Rank	1	3	2

Response Table for Means

Level	Speed	Feed	DOC
1	0.5377	0.4773	0.4367
2	0.4430	0.4273	0.4357
3	0.3980	0.4740	0.5063
Delta	0.1397	0.0500	0.0707
Rank	1	3	2

General Linear Model: RA NON COOLANT versus Speed, Feed, DOC

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Speed	Fixed	3	1000, 1500, 2000
Feed	Fixed	3	1200, 1400, 1600
DOC	Fixed	3	0.25, 0.50, 0.75

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	0.030494	0.015247	14.68	0.064
Feed	2	0.004689	0.002344	2.26	0.307
DOC	2	0.009848	0.004924	4.74	0.174
Error	2	0.002078	0.001039		
Total	8	0.047108			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0322301	95.59%	82.36%	10.69%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.4596	0.0107	42.78	0.001	
Speed					
1000	0.0781	0.0152	5.14	0.036	1.33
1500	-0.0166	0.0152	-1.09	0.390	1.33
Feed					
1200	0.0178	0.0152	1.17	0.363	1.33
1400	-0.0322	0.0152	-2.12	0.168	1.33
DOC					
0.25	-0.0229	0.0152	-1.51	0.271	1.33
0.50	-0.0239	0.0152	-1.57	0.257	1.33

Regression Equation

RA NON COOLANT = 0.4596 + 0.0781 Speed_1000 - 0.0166 Speed_1500 - 0.0616 Speed_2000
+ 0.0178 Feed_1200 - 0.0322 Feed_1400 + 0.0144 Feed_1600 - 0.0229 DOC_0.25
- 0.0239 DOC_0.50 + 0.0468 DOC_0.75

5. FLATNESS (ANALYSIS OF RESULT)

Table-5.1 Analysis of Result-Flatness error –Without coolant

trial no.	designation	speed	feed	doc	flat -woc	snra1
1	$A_1B_1C_1$	1000	1200	0.25	0.020	33.9794
2	$A_1B_2C_2$	1000	1400	0.50	0.028	31.0568
3	$A_1B_3C_3$	1000	1600	0.75	0.030	30.4576
4	$A_2B_1C_2$	1500	1200	0.50	0.017	35.3910
5	$A_2B_2C_3$	1500	1400	0.75	0.043	27.3306
6	$A_2B_3C_1$	1500	1600	0.25	0.037	28.6360
7	$A_3B_1C_3$	2000	1200	0.75	0.026	31.7005
8	$A_3B_2C_1$	2000	1400	0.25	0.032	29.8970
9	$A_3B_3C_2$	2000	1600	0.50	0.017	35.3910

5.1 FLATNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER

Table 5.2 Response Table for Signal to Noise Ratios-Smaller is better-Flatness error

Level	speed	Feed	doc
1	31.83	33.69	30.84
2	30.45	29.43	33.95
3	32.33	31.49	29.83
Delta	1.88	4.26	4.12
Rank	3	1	2

5.3 Response Table for Means

Level	speed	Feed	doc
1	0.02600	0.02100	0.02967
2	0.03233	0.03433	0.02067
3	0.02500	0.02800	0.03300
Delta	0.00733	0.01333	0.01233
Rank	3	1	2

5.2 General Linear Model: FLAT versus SPEED, FEED, DOC

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
SPEED	fixed	3	1000,1500,2000
FEED	fixed	3	1200,1400,1600
DOC	fixed	3	0.25,0.50,0.75

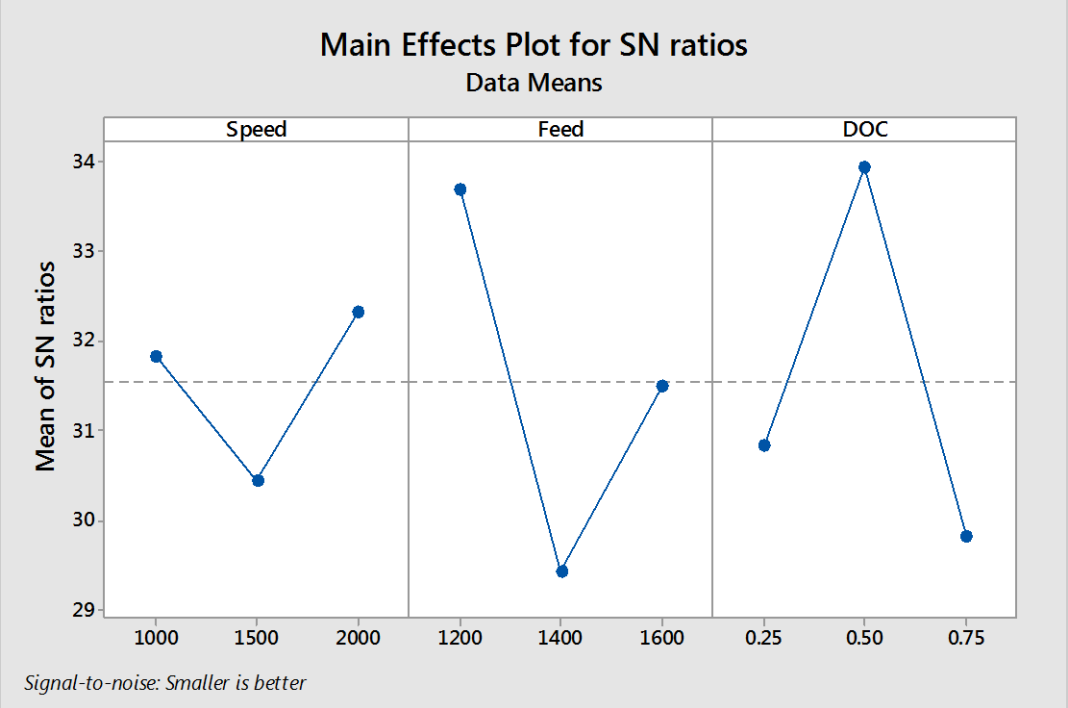
Table 5.4 Analysis of Variance-Flatness error

Source	DF	Seq SS	Adj SS	F	P	% OF CONTRIBUTION
SPEED	2	0.000095	0.000047	3.21	0.237	14
FEED	2	0.000267	0.000133	9.03	0.100	41
DOC	2	0.000244	0.00012	8.26	0.108	38
Error	2	0.000030	0.000015			7
Total	8	0.000636				

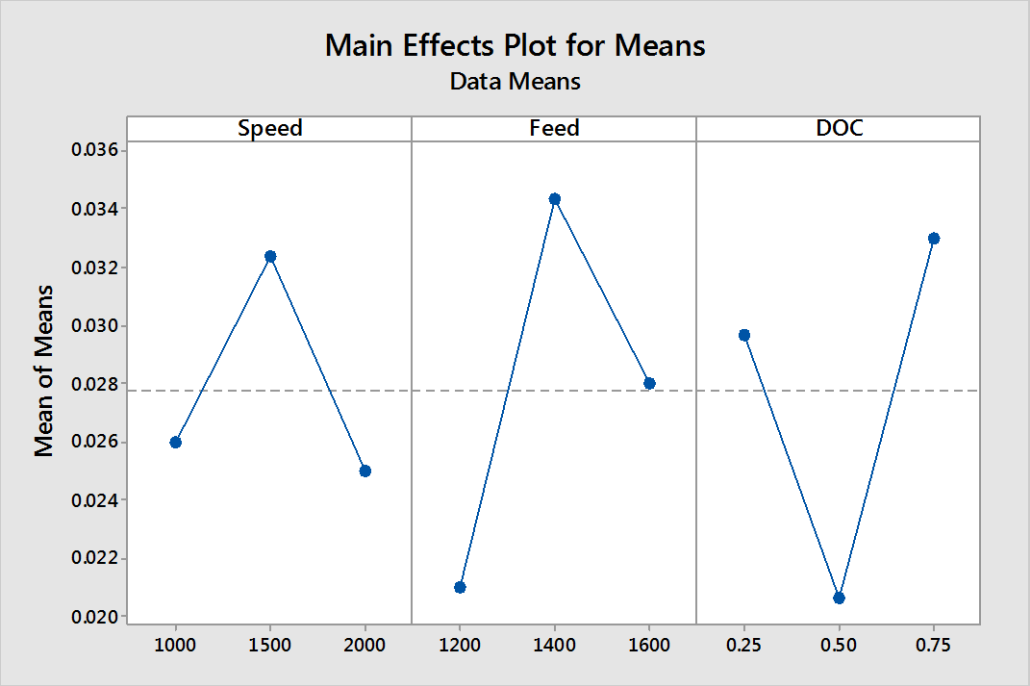
Regression Equation

FLATNESS ERROR WITH OUTCOOLANT = 0.02778 - 0.00178 Speed_1000 + 0.00456 Speed_1500 - 0.00278 Speed_2000
- 0.00678 Feed_1200 + 0.00656 Feed_1400 + 0.00022 Feed_1600
+ 0.00189 DOC_0.25 - 0.00711 DOC_0.50 + 0.00522 DOC_0.75

Main Effects Plot for SN ratios



Main Effects Plot for Means



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Taguchi Analysis: FLATNESS ERROR WITH OUT COOLANT versus Speed, Feed, DOC

Response Table for Signal to Noise Ratios
Smaller is better

Level	Speed	Feed	DOC
1	31.83	33.69	30.84
2	30.45	29.43	33.95
3	32.33	31.49	29.83
Delta	1.88	4.26	4.12
Rank	3	1	2

Response Table for Means

Level	Speed	Feed	DOC
1	0.02600	0.02100	0.02967
2	0.03233	0.03433	0.02067
3	0.02500	0.02800	0.03300
Delta	0.00733	0.01333	0.01233
Rank	3	1	2

General Linear Model: FLAT NON COOLANT versus Speed, Feed, DOC

Method
Factor coding (-1, 0, +1)
Factor Information

Factor	Type	Levels	Values
Speed	Fixed	3	1000, 1500, 2000
Feed	Fixed	3	1200, 1400, 1600
DOC	Fixed	3	0.25, 0.50, 0.75

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	0.000095	0.000047	3.21	0.237
Feed	2	0.000267	0.000133	9.03	0.100
DOC	2	0.000244	0.000122	8.26	0.108
Error	2	0.000030	0.000015		
Total	8	0.000636			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0038442	95.35%	81.40%	5.83%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.02778	0.00128	21.68	0.002	
Speed					
1000	-0.00178	0.00181	-0.98	0.430	1.33
1500	0.00456	0.00181	2.51	0.128	1.33
Feed					
1200	-0.00678	0.00181	-3.74	0.065	1.33
1400	0.00656	0.00181	3.62	0.069	1.33
DOC					
0.25	0.00189	0.00181	1.04	0.407	1.33
0.50	-0.00711	0.00181	-3.92	0.059	1.33

Regression Equation

FLAT NON COOLANT = 0.02778 - 0.00178 Speed_1000 + 0.00456 Speed_1500 - 0.00278 Speed_2000
- 0.00678 Feed_1200 + 0.00656 Feed_1400 + 0.00022 Feed_1600
+ 0.00189 DOC_0.25 - 0.00711 DOC_0.50 + 0.00522 DOC_0.75

6.RESULT&CONCLUSION

In this experimental study, the Taguchi technique and ANOVA were used to obtain optimal milling parameters of Al 2014 under dry and wet conditions. The experimental results were evaluated using ANOVA. The following conclusion can be drawn. In this study, the Taguchi technique and ANOVA were used to obtain optimal parameters in the face milling of aluminum analyzed under Dry and wet conditions .Low Surface roughness value and Flatness Error were obtained during the dry condition face milling operation. The experimental results were evaluated using Taguchi technique of the dry conditioned machining samples. The following conclusion can be drawn.

6.1 OPTIMAL CONTROL FACTOR

1. Surface Roughness-A3(Speed-2000) B2(Feed-1400mm/min)C1(DOC-0.25mm)

2. Machining Timing- A1(Speed-1000) B2(Feed-1600mm/min)C2(DOC-0.50mm)

3. Minimum Flatness Error- A3(Speed-2000) B1(Feed-1200mm/min)C2(DOC-0.50mm)

6.2 Percentage of contribution of Process parameter

1. Machining Timing-DOC-66%

2. Surface Roughness- Speed-64%

3. Flatness Error - Feed-41%

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