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Parametric Modelling of Drilling Parameters for Surface Roughness of Hole in Al 6082 Alloy

Narendra Kumar[1]*, Gaurav Gautam[2], Aditya Kumar Padap[1], Divya Singh[1], Mayank Kapoor[1], Anita Mohan[3], Sunil Mohan[4]

[1]*Department of Mechanical Engineering, B.I.E.T, Jhansi, India*

[2]*Department of Metallurgical and Materials Engineering, I.I.T, Roorkee, India*

[3]*Department of Physics, I.I.T (BHU), Varanasi, India*

[4]*Centre of Advanced Study, Department of Metallurgical Engineering, I.I.T (BHU), Varanasi, India*

ABSTRACT

Present study depicts application of central composite rotatable design (CCRD) of response surface methodology (RSM) to develop a mathematical model for surface roughness of a hole. Model establishes the functional relationship between drilling parameters and surface roughness of hole in Al6082 alloy. The experimental plan and analysis is based on CCRD array taking spindle speed (rpm), feed rate (mm/rev), and drill diameter (mm) as operating parameters for experiments. ANOVA results showed that large drill diameter results in more material removal which results in higher surface roughness. There is overall increase in surface roughness with increase in feed rate but significant decrease in surface roughness with increase in spindle speed.

Keywords – Al 6082 Alloy, ANOVA, CCRD, Drilling, Modelling

I INTRODUCTION

Today, in the competitive environment, production of high quality products is the main concern of the industries. In drilling operation product quality can be measured in terms of accuracy and surface finish of a hole [1]. Surface finish can be judge by surface roughness which is one of the critical performance parameter in many applications. Surface roughness significantly affects the mechanical, tribological and electrical properties of machined parts such as fatigue behaviour, corrosion resistance, creep life, friction, wear, lubrication, light reflection and electrical conductivity, etc. [2]. During drilling, surface roughness is influences by many parameters like, tool geometry, cutting speed, feed, drill diameter, tool and work piece material etc. [3]. A large number of reports are available in literature which deals with optimization of drilling parameters by using multiple techniques for maximize material removal with minimum surface roughness of hole. Kilickap et al. [4] studied the effect of machining parameters on the surface roughness in drilling of AISI 1045 steel and developed RSM based mathematical model. Cicek et al. [5] studied the effects of cryogenic treatment and drilling parameters on surface quality of hole in the drilling of AISI 304 stainless steel under dry drilling conditions.

They reported that feed rate and cutting speed were the most significant factors which affect the surface roughness and roundness error of the hole. Garg et al. [6] used Face centred design to optimize cutting conditions (i.e. cutting speed, feed, wet and dry cutting, and depth of hole) for minimum surface roughness in drilling of AISI H11. It was observed that feed is the most significant factor which affects the surface roughness.

After comprehensive study of literature review it seems that studies on nonferrous aluminium alloys using RSM based CCRD are not reported. Therefore, Al 6082 alloy has been chosen in the present study as this alloy is widely used in automobile, aerospace, marine and construction, due to its low cost, medium strength, good formability, weldabilty, excellent corrosion resistance, and higher thermal conductivity. Moreover it has wide applications in the field of high stress application, bridges, trusses, cranes, transport application, etc. [7, 8]. An effort is made to study the effect of process parameters on surface roughness of drilled hole in Al6082 alloy. Moreover a functional relationship between the parameters is also established.

II EXPERIMENTAL SETUP

2.1 Materials and equipment used

The work piece material Al6082 alloy (Al-Mg-Si) has been procured in the form of rod having 25mm diameter. High speed steel was used as drill material. Experiments were carried out on radial drilling machine and Surf test SJ-301 (Mitutoyo) was used for measuring surface roughness of the drilled hole.

2.2 RSM and CCRD

RSM establishes mathematical model which depicts a functional relationship between measured responses and the important input parameters. CCRD has been employed to reduce the number of experiments and, due to the rotatability condition, it involves same standard error at all the points which are equidistant from the designed centre [9]. In the present study three parameters, spindle speed (rpm), feed rate (mm/rev) and drill diameter (mm) have been used at five different levels to study the influence and predicting the relationship with the roughness of drilled surface. Selected parameters and their levels are shown in Table 1. Total twenty experiments were performed as per the standard CCRD design matrix as shown in Table 2.The nonlinear relationship among the process parameters, and response can be expressed by the following equation [7]:

$$\eta = \beta_o + \Sigma_{j=1}^{k} \beta_j x_i + \Sigma_{j=1}^{k} \beta_{jj} x_j^2 + \Sigma\Sigma_{i<j=2}^{k} \beta_{ij} x_i x_j \quad \textbf{(1)}$$

Where η is response; xi (1, 2, …,k) is the coded level of k quantitative variables; βo is the constant term, where βj, βjj, and βij are the coefficients of the linear equation. For empirical mathematical modelling, a software package MINITAB 17 (student version) has been used to find out the coefficients of mathematical modelling based on the response surface regression form.

III RESULTS AND DISCUSSION

3.1 Development and analysis of mathematical model

The mathematical relationship obtained for analysing the influence of various parameters on surface roughness average value (Ra) is given by equation (2)

$$\mathbf{Ra} = 2.187 - 0.552\,A + 0.145\,B + 0.286\,C + 0.201\,A^2 - 0.001\,B^2 + 0.528\,C^2 - 0.221\,A\times B - 0.101\,A\times C + 0.384\,B\times C \qquad \mathbf{(2)}$$

Run	Coded parameter			Actual parameter			Surface roughness (µm)
				Spindle speed (rev/min)	Feed rate(mm/rev)	Drill diameter (mm)	
1	-1	-1	-1	180	0.3	13	2.78
2	1	-1	-1	650	0.3	13	3.72
3	-1	1	-1	180	0.75	13	3.81
4	1	1	-1	650	0.75	13	2.28
5	-1	-1	1	180	0.3	15	2.66
6	1	-1	1	650	0.3	15	1.61
7	-1	1	1	180	0.75	15	3.64
8	1	1	1	650	0.75	15	3.29
9	-1.682	0	0	70	0.5	14	4.32
10	1.682	0	0	900	0.5	14	1.02
11	0	-1.682	0	250	0.2	14	2.18
12	0	1.682	0	250	1.25	14	2.02
13	0	0	-1.682	250	0.5	12	2.02
14	0	0	1.682	250	0.5	16	5.17
15	0	0	0	250	0.5	14	1.73
16	0	0	0	250	0.5	14	2.03
17	0	0	0	250	0.5	14	1.22
18	0	0	0	250	0.5	14	3.62
19	0	0	0	250	0.5	14	2.25
20	0	0	0	250	0.5	14	2.30

Table 2- Drilling parameters and their levels

Symbol	Parameters	Levels				
		- 1.682	**- 1**	**0**	**1**	**1.682**
A	Spindle Speed (rev/min)	70	180	250	650	900
B	Feed Rate (mm/rev)	0.20	0.30	0.50	0.75	1.25
C	Drill Diameter (mm)	12	13	14	15	16

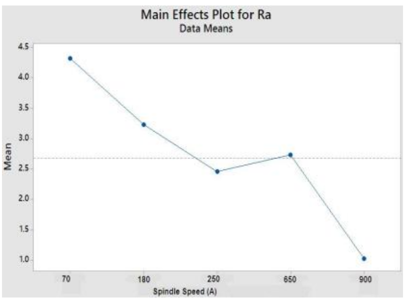
Table 3- CCRD design matrix and experimental data for surface roughness

Table 4, shows ANOVA results for developed model and percentage contribution of each parameter over the surface roughness. It is clear from the table that percentage contribution for the model is 81.74%. Linear interaction between the parameters is dominant with percentage contribution of 64.85%, while individually spindle speed is the most dominant factor with percentage contribution of 50.58% followed by drill diameter with percentage contribution of 9.98% and feed rate with percentage contribution of 4.29%. This clearly indicates that the surface roughness is mainly responded to spindle speed.

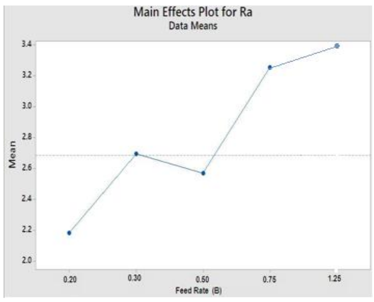
3.2 Main effect plots for surface roughness

To study the individual effect of parameters on surface roughness, main effect plots showing the variation of surface roughness with spindle speed (A), feed rate (B) and drill diameter (C) are drawn in Fig.1 (a) -1(c). From the Fig. 1(a), overall decrease in surface roughness is observed with increase in speed however it follows reverse trend with feed rate and drill diameter. Higher spindle speed helps to remove excess heat rapidly and also ejects chips produced during drilling process which results in decrease in surface roughness. Increased surface roughness at high feed rate and drill diameter may be attributed to large amount of material removal and tool wear. Moreover large amount of heat generation also leads to poor surface finish.

(a)



(b)



(c)

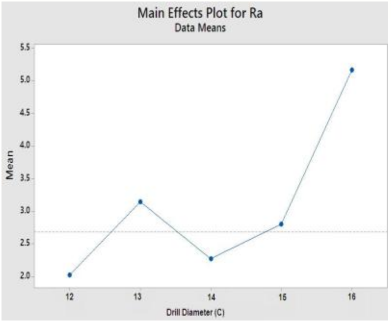


Fig. 1 Main effect plots between surface roughness and (a) spindle speed (b) feed rate (c) drill diameter

3.3 Interaction effect plots

The interaction effect between the parameters can be understood by the 3-D response surface plots shown in Fig.2 (a)-(c). The combined effect shown in Fig.2 (a) indicates that surface roughness has maximum value at 70 rpm spindle speed and 1.25 mm/rev feed rate. It also clear from ANOVA Table 4, that spindle speed has more influence on surface roughness as compared to feed rate.

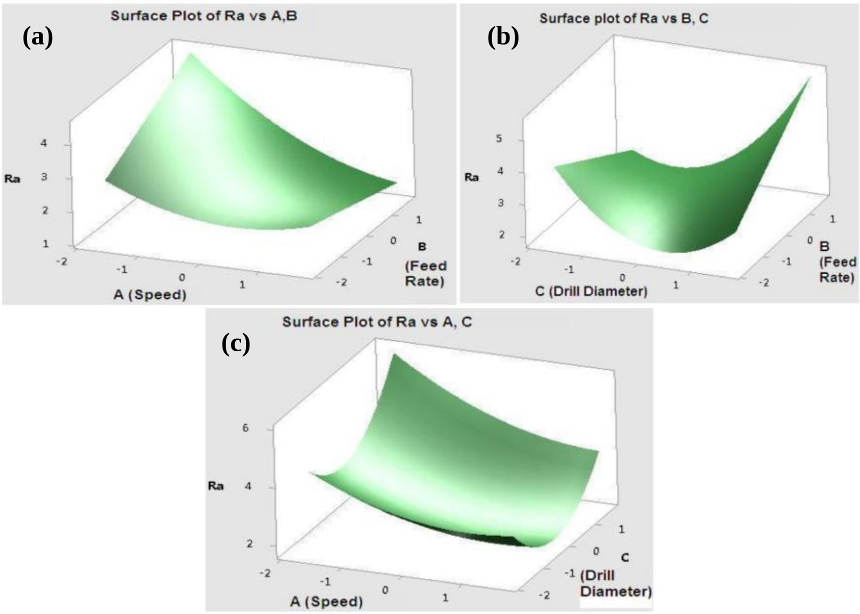


Fig.2(a)-(c) 3-D response surface plot for surface roughness variation with spindle speed, feed rate and drill diameter

Table 4 - ANOVA results for surface roughness model

Source	DF	Adj SS	Adj MS	F- value	P -value	Contribution (%)
Model	9	711.46	129.079	12.04	0.063	81.74
Linear	3	556.82	185.607	27.32	0.075	64.85
A	1	416.28	416.277	68.62	0.075	50.58
B	1	28.73	38.733	8.64	0.105	4.29
C	1	111.81	111.810	18.67	0.087	9.98
Square	3	138.123	46.574	5.67	0.092	10.63
A^2	1	18	25.7995	3.75	0.048	1.83
B^2	1	0.001	0.001	0.00	0.997	0.89
C^2	1	120.122	90.1220	20.81	0.470	7.91
2-way interaction	3	16.517	15.5058	0.51	0.684	6.26
A×B	1	3.916	3.9161	0.36	0.560	1.77
A×C	1	0.820	0.8201	0.08	0.788	0.23
B×C	1	11.781	11.7811	1.09	0.321	4.06
Error	10	47.861	10.7861			18.26
Lack of Fit	5	44.474	15.0948	35.54	0.010	14.46
Pure Error	5	3.387	1.64774			3.80
Total	19	759.321				100.00

Surface roughness gradually decreases with increasing the diameter up to 15mm and beyond it follows reverse trend. It is clearly indicated that drill diameter has more influence on than feed rate as shown in Fig. 2(b). Fig.2(c) also shows that effect of spindle speed is more significant as compared to drill diameter.

IV CONCLUSION

From the present study following conclusion can be drawn:

1. Second order mathematical model for surface roughness has been developed using RSM.

2. Spindle speed is the most dominant factor in surface roughness analysis followed by drill diameter and feed rate.

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REFERENCES

[1] N. S. Kurzekar, and M.S. Tufail, A review on optimization of drilling process parameters of AISI 304 austenite stainless steel by using response surface methodology, International Journal of Engineering Development and Research, 4(2), 2016,402-405.

[2] M. Venkata Ramana, A. Venkata Vishnu, G. Krishna Mohan Rao, and D. Hanumantha Rao, Experimental investigations, optimization of process parameters and mathematical modelling in turning of titanium alloy under different lubricant conditions. IOSR Journal of Engineering, 2(1), 2012, 86-101.

[3] J. Pradeep Kumar, and P.Packiaraj, Effect of drilling parameters on surface roughness, tool wear, material removal rate and hole diameter error in drilling of OHNS, International Journal of Advanced Engineering Research and Studies, 1(3),2012,150-154.

[4] E. Kilickap, M. Huseyinoglu , and A. Yardimeden, Optimization of drilling parameters on surface roughness in drilling of AISI 1045 using response surface methodology and genetic algorithm, International Journal of Advanced Manufacturing Technology ,52(1-4), 2011,79–88.

[5] A. Çiçek , T. Kıvak , and E. Ekici Optimization of drilling parameters using taguchi technique and response surface methodology (RSM) in drilling of AISI 304 steel with cryogenically treated HSS drills, Journal of Intelligent Manufacturing, 2013, DOI 10.1007/S10845-013-0783-5, 3351–3357.

[6] S. Garg and R. K. Goyal, A study of surface roughness in drilling of AISI H11 die steel using face centered design, International Journal for Innovative Research in Science & Technology, 1, 2015, 6-8.

[7] D. K. Vishwakarma, N. Kumar, and A. K. Padap, Modelling and optimization of aging parameters for thermal properties of al 6082 alloy using response surface methodology, Materials Research Express,4(4),2017, 046502.

[8] P. Sharma, D. Khanduja, and S. Sharma, Dry sliding wear investigation of Al6082/Gr metal matrix composites by response surface methodology, Journal of Materials Research and Technology,5(1),2016,29-36.

[9] D.C. Montgomery, Design and Analysis of Experiments, John Wiley & Sons, New York, 2001.