Optimization Turning Process Parameters of Aluminum Alloy 5083 using Response Surface Methodology

M. P. Prabakaran[1]
Assistant professor, Department of Mechanical Engineering
SBM College of Engineering and Technology,
Dindigul-624005

G. R. Kannan[2]
Professor, Department of Mechanical Engineering
PSNA College of Engineering and Technology, Dindigul-624622

K. Thirupathi[3]
Assistant professor, Department of Mechanical Engineering
SBM College of Engineering and Technology, Dindigul-624005

A. Hari prakash[4]
Assistant professor, Department of Mechanical Engineering
SBM College of Engineering and Technology, Dindigul-624005

Abstract - **Aluminum alloy are widely used for demanding structural applications due to good combination of formability, corrosion resistances and mechanical properties. This work deals with the Aluminum alloy 5083. Among the following process parameter the cutting speed, feed rate, depth of cut for the purpose of analysis. The twenty experiments were conducted as per central composite face centered design for turning machining the process of Aluminum alloy 5083 and the results are tabulated. The Response surface methodology is utilized to develop an effective mathematical model to predict surface finish. A comparison study is made for tabulated values and experimental values for surface finish by using analysis of variance. The model found statistically fit for 95% confidence level.**

Key words - Machining, Aluminum alloy, Surface finish, CCD, ANOVA, RSM.

1. INTRODUCTION

Machining, the most widespread process for shaping metal, has become a very significant aspect of modern society and industry. The importance of the machining process is evident by the observation that nearly every device used by humanity in day-to-day life at least one machined part or surface. Weight saving materials is more important, especially in the automotive and aerospace industries. Design engineers would thus like to make more extensive use of light metals such as aluminium, titanium, magnesium and their alloys. It is represent the highest volume (90%) of extruded aluminium products in western countries. Aluminium alloys are alloys in which aluminium is the predominant metal. These alloys with a wide range of properties are used in engineering structures. It has generally good mechanical properties and is heat treatable and weld able. The 5083 aluminium alloys are commonly used for boat building and shipbuilding, and other marine and saltwater sensitive shore applications; it is also used in extruded shapes for architecture, particularly window frames, door frames, roofs, furniture, stair rails, and in pipe railings. It is typically produced with very smooth surfaces fit for anodizing.

2. LITERATURE SURVEY

H.K.Dave et. al. [1] studied the effect of machining conditions on MRR and surface roughness during turning of different grade of EN materials using Tin coated cutting tools by Taguchi method. Also used MINITAB statistical software has been used for the analysis the effect of cutting parameters. Neseli et al. [2] experimented to optimization of tool geometry parameters for turning operations based on the response surface methodology. In this study, experiments were designed by using Taguchi L27 ortogonal array. The effect of tool geometry parameters on the surface roughness during turning of AISI 1040 steel obtained through response surface methodology (RSM) and prediction model was developed related to average surface roughness (Ra). K. Arun Vikram et al. [3] investigated the effect of machining parameters on surface roughness in hard turning process for three different materials like EN8 steel, Aluminium alloy and Copper alloy under dry conditions. Three parameters like cutting speed, feed and material hardness used during their experimental studies. Empirical model for surface roughness developed with help of MINITAB software by means of nonlinear regression data mining method done in MINITAB. Astrand et al [4] showed the coating layouts and cutting tool edge geometry can significantly affect heat distribution into the cutting tool. The paper clearly shows the role and potential benefits of applying different top coats on the rake and flank faces with regards contact phenomenon, impact on thermal shielding and tool wear. Ozel et al [5] found, the predicted forces and tool wear contours are compared with experiments. The temperature distributions and tool wear contours demonstrate some advantages of coated insert designs. Krishnakumar et al [6] approached, unlike traditional non-linear optimization methods for fixture optimization reported in the literature, the GA approach is particularly suited for problems where there does not exist a well-defined mathematical relationship between the objective function and the design variables.

3. EXPERIMENTAL METHODOLOGY

3.1 Plan of Experiments

An important stage in response surface model generation by RSM is the planning of experiments. The factors which have a significant influence on surface roughness of aluminum alloy were identified. They are feed, speed and depth of cut of turning machine. Large numbers of trial runs were carried out aluminum alloy 5083 bar 320 × 60mm using to determine maximum and minimum values of machining parameters.

Table: 1 Process parameters and their actual values

Factors	Notation	Unit	Factor Level		
			Low	Middle	High
Cutting Speed	S	Rpm	300	600	900
Feed rate	F	mm/rev	0.05	0.10	0.15
Depth of cut	D	Mm	0.	1	1.5

3.2 Design of experiment

The statistical design of experiment is the process of planning the experiment so that appropriate data could be collected which may be analyzed by statistical methods resulting in valid object conditions. Design of experiments is the design of all information gathering exercises where variation is present, whether under the full control of the experiment. The response variables like surface roughness were recorded using surface roughness tester. The surface finish in machining can be measured directly by surface roughness, it has stylus probe to read the surface finish with in the specified distance. The distance to be moved by the probe can be set by the operator.

3.3 Response surface methodology

Response surface methodology is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments the objective is to optimize a response which is influenced by several independent variables. An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response. The second order mathematical models have been developed to predict the surface roughness.

$$yi = \beta_0 + \sum_{j=1}^{q} \beta jxj + \sum_{j=1}^{q} \beta jjxj^2 + \sum \sum_{i<j}^{3} \beta ij\, xi\, xj$$

Where y_i is response, i.e., surface roughness; x_j represents cutting speed, feed rate depth of cut β_0, β_j, β_{jj}, and β_{ij} represent the constant, linear, quadratic, and interaction terms, respectively. The three factors, the selected polynomial could be expressed as

SURFACE ROUGHNESS $= b_0 + b_1$ (S) $+ b_2$ (F) $+ b_3$ (D) $+ b_{11}$ (S^2) $+ b_{22}$ (F^2) $+ b_{33}$ (D^2) $+ b_{12}$ (SF) $+ b_{13}$ (SD) $+ b_{23}$ (FD).

The cutting force, surface roughness and tool wear obtained from experimental results for different combination of parameters is given as input to the design expert software, and a second order mathematical model for predicting surface roughness is developed. The developed mathematical model for machining is given below.

SURFACE ROUGHNESS = 1.64-0.016(S)+5.000E^{-003}(F)0.66(D)+0.45(SF)+ 0.095(SD)+0.098(FD)+ 0.61(S^2)+0.51(F^2)+0.12(D^2).

A total of 20 experiments were conducted at different levels of parameters to obtain a machining operation. The values of surface roughness obtained from experiments and those predicted from response surface model along with design matrix are tabulated.

Table: 2 Process parameters and their experimental values.

S.no	Cutting Speed (rpm) (S)	Feed rate (mm/rev)(F)	Depth of Cut (mm)(D)	Surface Roughness(Ra)	
				Experimental values	Predicted values
1	300	0.05	0.5	3	3.7801
2	900	0.05	0.5	2.1	3.0720
3	300	0.15	0.5	2.7	3.1090
4	900	0.15	0.5	3.4	3.1890
5	300	0.05	2	2.1	2.4880
6	900	0.05	2	1.99	1.7510
7	300	0.15	2	2	1.7980
8	900	0.15	2	2.4	2.8510
9	300	0.1	1.25	2.58	2.2656
10	900	0.1	1.25	2.6	2.2336
11	600	0.05	1.25	2.39	2.1496
12	600	0.15	1.25	2.6	2.1596
13	600	0.1	0.5	2.7	2.4176
14	600	0.1	2	1.5	1.1016
15	600	0.1	1.25	1.42	1.6419

16	600	0.1	1.25	1.5	1.6419
17	600	0.1	1.25	1.46	1.6419
18	600	0.1	1.25	1.41	1.6419
19	600	0.1	1.25	1.3	1.6419
20	600	0.1	1.25	1.4	1.6419

4. RESULT AND DISCUSSION

4.1 Analysis of variance

Table: 3 ANOVA Result

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	3.831E+005	9	42570.50	62783.56	< 0.0001
A-Speed	1.806E+005	1	1.806E+005	2.664E+005	< 0.0001
B-Feed	2.025E+005	1	2.025E+005	2.986E+005	< 0.0001
C-Depth of cut	1.04	1	1.04	1.53	0.2445
AB	3.125E-006	1	3.125E-006	4.609E-006	0.9983
AC	3.125E-006	1	3.125E-006	4.609E-006	0.9983
BC	3.125E-006	1	3.125E-006	4.609E-006	0.9983
A^2	0.83	1	0.83	1.22	0.2946
B^2	0.83	1	0.83	1.22	0.2946
C^2	2.49	1	2.49	3.68	0.0841
Residual	6.78	10	0.68		
Lack of Fit	4.55	5	0.91	2.04	0.2259
Pure Error	2.23	5	0.45		
Cor Total	3.831E+005	19			

The Model F-value of 62783.56 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model. The "Lack of Fit F-value" of 2.04 implies the Lack of Fit is not significant relative to the pure error.

4.2 Analysis of response surface graphs

Response surfaces were developed for the empirical relationship, taking two parameters in the 'X' and 'Y' axis and response in 'Z' axis. The response surfaces clearly indicate the optimal response point. The response of surface roughness of the surface plots showing the effect of input parameters taken two at a time on surface roughness. The different colored surfaces show that the values of surface roughness obtained for the corresponding values of input parameters. The developed model for the, surface roughness is shown below:

SURFACEROUGHNESS = $1.64-0.016(S)+5.000E^{-003}(F)$ $0.66(D)+0.45(SF)+0.095(SD)+0.098(FD)+$ $0.61(S^2)+0.51(F^2)+0.12(D^2)$.

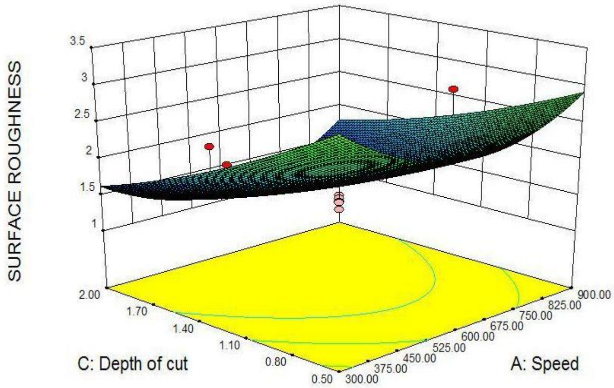

Figure: 1 Response surface due to interaction of depth of cut and speed on surface roughness

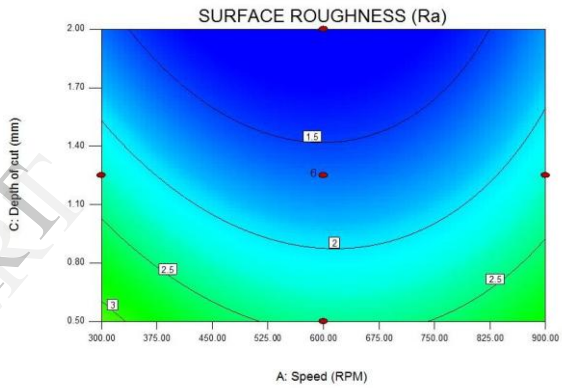

Figure : 2 counter plot to interaction of depth of cut and cutting speed on surface roughness

Figure 1&2 represent the three dimensional response surface plots for the response surface roughness obtained from the regression model .The response surface graphs for the surface roughness between feed rate and cutting speed on surface roughness. It can be seen that surface roughness increases gradually by increasing the speed and decreasing depth of cut. In other hand higher depth of cut lower spindle speed gives poor surface finishing.

CONCLUSION

In the study the following process parameter namely spindle speed, depth of cut and feed rate considered for the effect on surface finishing. Trail experiment of twenty numbers is conducted as per the central composite face centered design (CCFD) of full factorial design. The experimental values of surface finishing are noted for design condition.

- RSM model and the optimization results, the predicted and measured values are moderately close, which indicates that the developed model can be effectively used to predict the surface roughness.

- The surface roughness is found to be low at higher speeds and high at lower feed rates.
- The second order quadratic model was used to predict surface finishing values for experimental value by response surface methodology.
- A comparison study is made for tabulated values and experimental values for surface finish by using analysis of variance the model is statistically fit found on 95% confidence level.

REFERENCE

1. H. K. Davea, L. S. Patelb and H. K. Ravala, “Effect of machining conditions on MRR and surface roughness during CNC Turning of different Materials Using TiN Coated Cutting Tools – A Taguchi approach” International Journal of Industrial Engineering Computations.
2. Suleyman Neseli , Suleyman Yaldız , Erol Turkes, “Optimization of tool geometry parameters for turning operations based on the response surface methodology” Measurement 44 (2011) 580–587.
3. K. Arun Vikram, Ch. Ratnam, “Empirical model for Surface Roughness in hard turning based on Analysis of Machining Parameters and Hardness values of various Engineering Materials” International Journal of Engineering Research and Applications Vol. 2, Issue 3, May-Jun 2012, pp.3091-3097.
4. Astrand M, Selinder TI, Fietzke F, Klostermann H, PVDAl2O3-coated cemented carbide cutting tools, Surf Coat Tech, 2004.
5. Özel, T., et al, Investigations on the effects of multi-layered coated inserts in machining Ti–6Al–4V alloy with experiments and finite element simulations., CIRP Annals - Manufacturing Technology,2010.
6. S J Kim, K.S. Kim, H. Jang, Optimization of manufacturing parameters for a brake lining using Taguchi method, Journal of Materials Processing Technology,2003.
7. G.Sutter, L.Faure, A.Molinari, N.Rane, V.Pina, An experimental technique for the measurement of temperature fields for the orthogonal cutting in high speed machining, Int.J.Mach.Tools Manuf.43(2003)671-678
8. N.A.Abukhshim, P.T.Mativenga, M.A.Sheikh, Heat generation and temperature prediction in metal cutting; A review and implications for high speed machining,Int. J.Mach.ToolsManuf.46(2005)782-800
9. Robert W.Ivester, Tool temperature in orthogonal cutting of alloyed titanium, NAMRI/SME,Vol.39,2011
10. D.Dudzinski, A.Devillez, A,Moufki, D.Larrouquere, V.Zerrouki, J.Vigneau, A review of developments towards dry and high speed machining of Inconel 718 alloy. International journal of machine tools and manufacture 44 (2004) 439-456
11. J.Q.Xie, A.E.Bayoumi, and H.M.Zbib, Analytical and experimental study of shear localization in chip formation in orthogonal machining, ASM International, JMEPEG (1995)4:32-39
12. Abele.E and Frohlich.B, High speed milling of titanium alloy, Advances in production engineering management 3 (2008) 3, 131-140
13. L.B.Abhang and M.Hameedullah chip-tool interface temperature prediction model for turning process, JEST,Vol2(4), 2010, 382-393
14. J.J.Mason, R.V.Kaznaza-pena, effect of tool parameters on temperature fields in high speed machining, research engineer, CNWRA, Southwest research institute.