PREDICTION OF SURFACE ROUGHNESS IN END MILIING PROCESS OF Al 7075/ B_4C USING RESPONSE SURFACE METHODOLOGY

C.HARIKRISHNAN
Student
Department of Mechanical Engineering
Kumaraguru College of Technology
Coimbatore

harimech0145@gmail.com

Mr. K.KRISHNAMOORTHI
Assistant Professor
Department of Mechanical Engineering
Kumaraguru College of Technology

krishnamoorthi.k.mec@kct.ac.in

Abstract*- One of the most perceptions of quality in mechanical product is its physical look. One among the foremost necessary factors in physical look is that the surface roughness. This analysis focuses on study and analysis of surface quality improvement in end milling operation of Al 7075/B_4C metal matrix composite. Aluminium matrix composites (AMCs) are main key for advance engineering materials due to their ductility, strength and toughness. The present study investigate the effect of spindle speed, feed rate, depth of cut and varied percentage (% wt.) of B_4C on surface roughness in end milling of Al7075 alloy. To increase the mechanical properties, strength the of Al7075 alloy it is reinforced with varied composition (weight %) of Boron carbide using Stir casting method. Stir casting method is used to prepare the specimen due to better and even spread of reinforcement material. Experiments are conducted on a CNC milling machine according to design of experiments methodology. A response surface model for surface roughness from the observed values is developed using Response Surface Methodology. The result obtained using RSM gives a good prediction of surface roughness when compared to actual surface roughness. The experimental results were analyzed statistically to examine the influence of process parameters on surface roughness.

***Keywords:* End milling, Response surface methodology (RSM), Surface roughness.**

I INTRODUCTION

In modern world military would be less efficient without composites. The advantage of using composite materials is strength and stiffness combined with lightness along with design flexibilities. New composites have also been developed in recent times with different properties. Composite materials are new generation materials developed to meet the demands of enormous growth of technological changes of the industry. Composite materials or composites are engineering materials made from two or more constituent's materials that remain separate and distinct on macroscopic level while forming a single component.

Fearured effect of machining parameters on surface texture, with the combination of taguchi method along with statically analysis from the obtained results. Rake angle, feed, depth of cut and cutting speed as process parameters. Two flute tool was used for experimentation. The optimal values for the process parameters were inside the experimentation region. [5]

The most prevalent types of MMCs are aluminum alloys reinforcing with ceramic particles. These low-cost composites provide higher strength, stiffness and fatigue resistance with a negligible increase in density over the base alloy predicted and optimized the end milling process parameters of cast aluminum based MMC. Tool flank wear was optimizes using response surface methodology (RSM). Experimental plan was done using CCD central composite design. ANOVA based results indicated that the proposed mathematical factors can be adequately used for further studies also found that optimal cutting conditions were used to reduce tool flank. [3]

The density of most of the MMCs is nearly one third that of steel, resulting in highspecific strength and stiffness. Several studies have been done in thestudy the efficiency of different cutting tool materials, such as cemented carbide, coated carbide, and diamond in turning, milling, drilling, reaming, and threading of MMC materials. [1]

Aluminium alloy (LM6) is used in Marine, Automobile, Aerospace industries. One of the main disadvantages of this material system is that they exhibit reduced tribological properties. To develop a new material with greater wear resistance and enhanced tribological properties, without much compromising on the strength to weight ratio led to the development of metal matrix composites. Silicon carbide ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600°C with no strength loss. [7]

I the study the author focused on the influence of spindle speed, feed rate and depth of cut on the surface roughness of Al7075 alloy during end milling. The author Applied Taguchi optimization methodology to optimize the cutting parameters with different machining parameters 10mm end milling tool. Analysis of variance (ANOVA) is employed to analyse the effect of end milling parameters and he finally concluded that spindle speed and feed rate are the major significant parameters[5].

The author investigated the machinability of Al/Sic MMC and found that no (BUE) build-up edge were found while machining at lower depth of cut and lower feed rates. Carbide coated end mill cutters were used during the machining. Different compositions were made to ensure good results for surface finish. Interaction among them were also analysed to find best working optimal range. [1]

In the experiment author, analyzed the influence of cutting condition and tool geometry on surface roughness when slot end milling AL2014-T6. The parameters considered were the cutting speed, feed, depth of cut, concavity and axial relief angles of the end cutting edge of the end mill. Surface roughness models for both dry cutting and coolant. [2]

V.Mugendirana et al., Found that the optimize surface roughness and wall thickness through incremental forming on AA5052 Aluminium alloy at room temperature by controlling the effects of forming parameters was studied. Design of experiments has been used to study the effects of forming parameters those influence of three input parameters. The obtained results predict a predominant interaction between the forming parameters which can be effectively and efficiently identified to produce minimum surface roughness and maximum wall thickness. A second-order quadratic model has been obtained to predict the surface roughness (Ra) and wall thickness (t) as function of spindle speed.[10]

The author investigated to improve the performance of end milling process, and subsequently to improve productivity through proper selection of machining parameters. He also emphasizes that proper selection of parameters improves the machining of Al/SiC and the end milling process becomes improvedthereby making the machining process economical and feasible for its use in wide variety of industries.[6]

The author Conducted experiments based on three factors, two level and central composite face central design (CCD) with full factorial and the results are analyzed for surface roughness. According to the principle of Response Surface Methodology(RSM).[8]

Aluminum alloy is used for the investigated of the effect of main factors on the surface roughness in nodular cast iron FCD 400 face milling by carbide tool. The factors used are speed, feed rate and depth of cut. Preliminary experiments showed that the depth of cut does not affect the surface roughness fix depth of cut at 2 mm. The experiment had illustrated that the factor affecting surface roughness was feed rate and cutting speed with tendency for reduction of roughness value at lower feed rate and greater cutting speed. They concluded that the result also indicates that higher value of speed and lower feed rate tended to decrease the surface roughness.[4]

II EXPERIMENTAL SETUP

In the present project experimental study, the material to be machined was Al7075 alloy reinforced with boron carbide particles through stir-casting route was used for experimentation. The dimension of the specimen was of 100 mm × 50 mm × 10 mm. The milling tests were performed on HASS Computer Numerically Controlled (CNC) vertical milling machine as shown in figure 1. High speed steel (12mm diameter; 4 flutes) was elected for the experiment. The important factors influencing the Surface roughness (Ra) and their levels are presented in Table 1.

Table I: Parameters and their values at different levels:

PARAMETERS	UNITS	LEVELS				
		-2	-1	0	1	2
Spindle speed	Rpm	1500	2000	2500	3000	3500
Feed rate	mm/rev	0.005	0.01	0.015	0.025	0.02
Depth of cut	mm	0.5	1	1.5	2	2.5
Boron carbide	%wt	0	5	10	15	20

As the range of individual factor was wide, a central composite rotatable four-factor, five-level factorial design matrix was selected. The machining operations were carried out as per the conditions are given by the design matrix in HASS - CNC Vertical Milling Machine as shown in fig1. The selected design plan chose consists of 31 experiments.

The surface roughness of the machined test samples was measured using portable MITUTOYO SURFACE TEST PROFILOMETER with a cut off range of 0.8mm with a sampling length of 10mm.

ISSN 2229-5518

III RESPONSE SURFACE METHODOLOGY

Response surface methodology is a mathematical method used investigating problems in which several independent variables affect a dependent variable or response and the aim is to optimize the response. Three principal machining parameters such as the spindle speed (N), feed rate (F), Depth of cut (D) and % of B_4C (B) were taken. In this study, these machining parameters were chosen as the independent input variables.

The desired response was the Surface roughness (Ra) which is assumed to be affected by the above four principal machining parameters. The response surface roughness Ra can be expressed as a function of process parameters spindle speed (N), Feed rate (F), Depth of cut (D) and % of B_4C (B).

In the present investigation, RSM has been applied for developing the mathematical model in the form of multiple regression equations for the quality characteristic of the end milling of Al7075 aluminum alloy composites. Representing Surface roughness (Ra), the response is a function of spindle speed (N), Feed rate (F), Depth of cut (D) and % of B_4C (B), it can be expressed as,

$$Ra = f\{N, F, D, B\} \qquad (1)$$

Where Ra is the preferred response and F is the response function or response surface. In the process of analysis, the estimation of Ra was suggested using the fitted second-order polynomial regression model, which is called the quadratic model. The quadratic model of Ra can be written as follows,

$$Ra = b_0 + \Sigma b_i X_i + \Sigma b_{ii} X_i^2 + \Sigma b_{ij} X_i X_j \qquad (2)$$

Where b_0 is constant, b_i, b_{ii}, and b_{ij} represent the coefficients of linear, quadratic, and cross product terms, respectively.

The values of the coefficients of the polynomials were calculated by multiple regression methods. The design was generated and analyzed using Minitab statistical package. Statistical software Minitab 16 was used to calculate the values of these coefficients.

Figure 1.HASS - CNC Vertical Milling Machine

IV DEVELOPMENT OF MATHEMATICAL MODEL

The data which is presented in table II is analyzed using Minitab software is the initial model and includes all linear, interaction square terms. Based on equation the effects of the above-mentioned process parameters on the magnitude of the Ra have been calculated by computing the values of the coefficient were calculated using Minitab Software.

The importance of each coefficient was determined by Student's *t*-test and *p* values, which are listed in Table 3. The values of *p* less than 0.05 (i.e., p=0.05 or 95% confidence), which indicates that the model is considered statistically significant and the values greater than 0.05 indicate that the model terms are not significant. The regression equation for predicting surface roughness (Ra) is as follows:

Surface roughness (Ra) = 0.87000 – (038333A) + (072500B) + (0035000D) + (001708A^2) – (047197 C^2) + (0022083 D^2) + (003000 A^2) + (0. 045000B*D) + (0.025000 B*C) + (0.04000 C*D)

These give the coefficient for calculating the predicted value of surface roughness. Table III gives the statics analysis of linear, square and interaction terms as following table

Table II. Experimental design matrix and results:

EX. NO	Coded values				Surface roughness (µm)Ra	
	Spindle speed	Feed rate	D	% B_4C	Observe d value	Predicted Value
1	-1	-1	-1	-1	0.84	0.854277
2	1	-1	-1	-1	0.73	0.733611
3	-1	1	-1	-1	0.78	0.799277
4	1	1	-1	-1	0.77	0.798611
5	-1	-1	1	-1	0.68	0.680111
6	1	-1	1	-1	0.56	0.559445
7	-1	1	1	-1	0.72	0.725111
8	1	1	1	-1	0.71	0.724445
9	-1	-1	-1	1	0.71	0.710111
10	1	-1	-1	1	0.57	0.589445
11	-1	1	-1	1	0.82	0.835612
12	1	1	-1	1	0.87	0.834445
13	-1	-1	1	1	0.803	0.784277
14	1	-1	1	1	0.65	0.663611
15	-1	1	1	1	0.943	1.009277
16	1	1	1	1	0.97	1.008611

17	-2	0	0	0	0.92	0.928986
18	2	0	0	0	0.806	0.807654
19	0	-2	0	0	0.64	0.655
20	0	2	0	0	0.944	0.945
21	0	0	-2	0	0.59	0.609
22	0	0	2	0	0.61	0.60912
23	0	0	0	-2	0.72	0.73
24	0	0	0	2	0.84	0.87
25	0	0	0	0	0.84	0.8
26	0	0	0	0	0.86	0.87
27	0	0	0	0	0.86	0.87
28	0	0	0	0	0.86	0.87
29	0	0	0	0	0.86	0.87
30	0	0	0	0	0.86	0.87
31	0	0	0	0	0.86	0.87

IMPROVED MODEL:

Improved model is made shown in table III takes account only the major factors, factor square and factor interactions that are influencing on the surface roughness. Based on 5% confidence level of interval value of p <0.05, in linear terms spindle speed, feed rate, depth of cut, %wt of B_4C interaction plays an important role in affecting surface roughness.

Table III Statistic Analysis of improved model

Coef	P
0.860000	<0.000
-0.038333	<0.000
0.073850	<0.000
0.035000	<0.000
0.030000	<0.000
0.011500	<0.000
-0.036500	<0.000
0.027000	<0.000
0.024500	<0.000
-0.006500	<0.019
0.044500	<0.000
0.036000	<0.000
0.035000	<0.000

V RESULT AND DISCUSSION

The normality plot given in Fig. 2 shows that all the plots follow a clear pattern along the centre line, indicating all the interaction that affects the surface roughness of the material. From Fig 3 indicates that the maximum variation of -0.005 to 0.005which shows a high correlation that exists between fitted values observed values. This plot is the typical for testing the assumption of constant variables. If the assumption is satisfied, the residual plot is structure less.

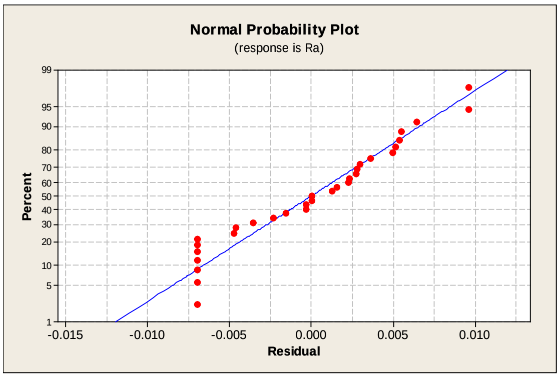


Fig. 2: Normality probability plot for surface roughness

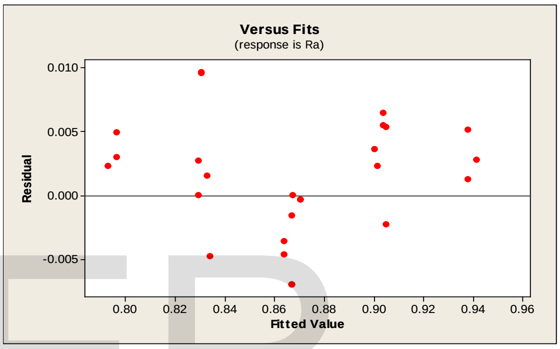


Fig. 3: Residual Vs fitted values for surface roughness

By Fig. 2 normality plot it is clearly observed that the residuals falls on a straight line, also means that the errors are distributed normally and regression model is well fitted for the observed surface roughness values. The plot is testing of assumption of constant values with an structure less that is no obvious pattern, shows the residual values along with fitted values for surface roughness, also found that high correlation occurs between values. With the smaller value than the critical value it can be concluded that assumption for the constant variables of residuals is acceptable.

Following the residual and regression analysis main effect plot were made to find how Ra varies to different parameters (spindle speed, feed rate, depth of cut, and % wt of B4C) which we taken for the optimization. The mean values are plotted from 0.80 – 0.96. Based on the figure values which obtained from the MiniTab software some major conclusions are made and explained in the upcoming figures.

Following conclusions are made from Fig. 4.

Speed: An increase in speed will reduce the surface roughness value, because of the lower cutting speed larger chips are produced creating a rough surface. While on higher cutting speeds chip formation is reduced or the chips vanish forming a good surface finish. This conclusion is made is also supported by practical values.

Feed: In this case increase in feed values will also increase the surface roughness values. Heat generation during the higher feed rates is also a factor for increase surface roughness.

Depth of cut: Increasing the depth of cut increases the surface roughness values.

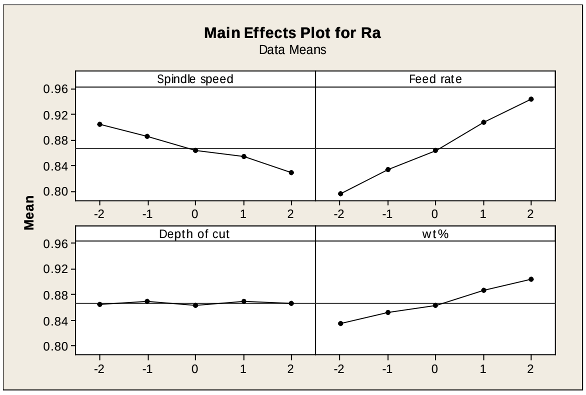


Fig. 4: Main effect plot for surface roughness

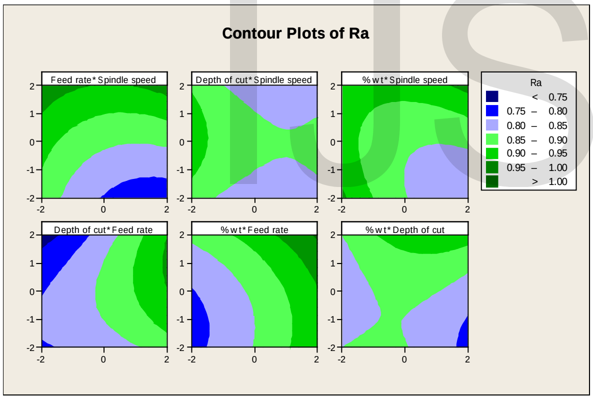


Fig. 5 Interaction effect on machining parameters on Ra

It is observed from fig 5 that the increase in the B_4C increases the hardness of the composite. The contour graph between these most significant process parameter interactions is shown in fig1. From the counter graph it is found that the most significant interaction effect was found between Feed rate vs spindle speed, % wt of B_4C vs Spindle speed, Depth of cut vs Feed rate.

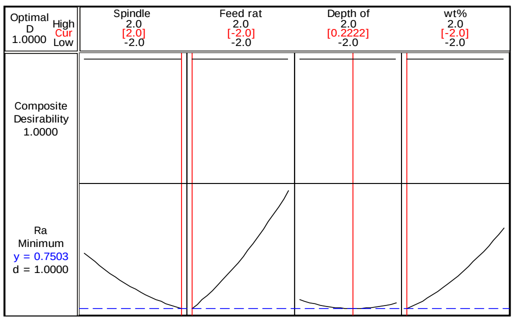
From the Fig1 graph Feed rate Vs spindle speed, it clearly shows that when feed rate increases the surface roughness value increases while at medium cutting speed and feed gives optimal surface roughness value when the spindle speed or feed rate increases the value of surface roughness gets increases. At least feed rate Ra value is higher as it increases gradually the Ra value gets lower the colours from the graph clearly the values of Ra. In case of %wt of B_4C Vs Spindle speed, it is observed that at 20% composition the hardness value is large and making it difficult for machining getting Ra value 0.85–0.90 μm which is high roughness for the composite material. Optimal values for surface roughness occur when machining at 15%wt of B_4C at 1500rpm.

Depth of cut vs. Feed rate, the Ra values gradually increases as feed rate increases at higher feed rate values change from 0.85 – 0.90 μm. Increase in feed rate will lead to increase tool wear as outcome.

CONCLUSION:

1. The experiments were conducted on a vertical milling machine for the machining of Al7075/B_4C and the effect of process machining spindle speed, feed rate; Depth of cut and various percentage weight of boron carbide were studied.
2. Response Surface methodology is used to study the effect of these parameters and their interaction on surface roughness.
3. An empirical equation is formed using RSM in Minitab software to predict the surface roughness of Al7075/B_4C.The predicted value of the improved value gives better results when compared with the actual measured values.
4. In order of their influence feed rate and spindle speed are the most influence on surface roughness.
5. Depth of cut has less influence on surface roughness. The study also concluded that the effect of depth of cut is negligible based on 95% confidence level.

4.7 ANALYSIS FOR OPTIMIZATION OF THE RESPONSE:



The optimization plot for minimum surface roughness is shown in fig above it clearly shows that the highest desirability could be obtained at high cutting speed, lower feed rate, and lower depth of cut. The upper value is fixed as 0.984 and target is fixed as 0.8012. The parameter setting for achieving best surface finish as low as 0.7503 has been predicted as a spindle speed (*N*)

2500 rpm, Feed rate (*F*) 0.005 mm/rev, Depth of cut (*d*) 0.22 mm.

REFERENCES

1. H.Okten,T.erazuma,h.kautrn"Application Of Response Surface Methodology in Optimimum Cutting Conditions foe Surface Roughness" Journal of material processing technique.170(2005)11-16.
2. John D. Kechagias, Christos K. Ziogas, Menelaos K. Pappas, Ioannis E. Ntziatzias, "Parameter optimization during finish end milling of Al alloy 5083 using robust design, Proceedings of the World Congress on Engineering, Vol. 1, 2011.
3. K. Kadirgama, M. M. Noor, N. M. Zuki. N.M, M. M. Rahman, M. R. M. Rejab, R. Daud, K. A. Abou-El-Hossein, "Optimization of surface roughness in end milling on mould aluminium alloys (AA6061-T6) using response surface method and radian basis function network", Jordan Journal of Mechanical and Industrial Engineering, Vol. 2, 2008, 209- 214.
4. M.Seeman, G.Ganesan, R.Karthikeyan, and A.Velayudham (2010), Study on tool wear and surface roughness in machining of particulate aluminum metal matrix composite - response surface methodology approach, International Journal of Advanced Manufacturing Technology, Vol. 48, pp. 613–624.
5. Manna, 2003, A Study of machinability of Al/SiC Vol.140,pp. 711-716.
6. N.Suresh Kumar Reddy, Shin Kwang-Sup, and Minyang Yang (2008), Experimental study of surface integrity during end milling of Al/SiC particulate metal–matrix composites, Journal of Materials Processing Technology, Vol. 201, pp. 574–579.
7. Prashant Kumar, Suragimath, and G.K.Purohit(2013),A study on mechanical properties of aluminium alloy (LM6) reinforced with SiC and Fly Ash, IOSR Journal of Mechanical and Civil Engineering, Vol. 8, No. 5, pp. 13-18.
8. R. Arokiyadass , K Palanirarajan, N. Alagumoorthi (2011), Predictive modelling of surface roughness in end milling of Al/Sip metal matrix composite (2011),page 228-236.
9. R.N Nimase, P.M khodes (2015), Effect of machining parameters on surface roughness of Al-7075 in end milling (2015), page 2395-0072.
10. V.Mugendirana, A.Gnanavelbabu. "Parameter optimization for surface roughness and wall thickness on AA5052 Aluminium alloy by incremental forming using response surface methodology" (2014) 1991 – 2000.