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COMPREHENSIVE ANALYSIS OF MILLING PARAMETERS ON ALUMINIUM ALLOYS

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ABSTRACT

The end milling process is a broadly used material elimination process with manufacture by different shapes and profiles. End milling is a replacement of the conventional milling process and it's also used as an end mill tool for the machining process. The impact of different parameters sued in end milling process examples feed rate, depth of cut and spindle speed have been evaluated to Impact on Material Removal Rate (MRR) and surface roughness (Ra) by using Response Surface Method. This investigation is generated by a Box-behenken design. The aim of this work is to study the impact of process parameters in Aluminium alloy surface, and to integrate the mathematical model for Material removal rate and surface roughness on milling process. The quadratic model is best agreement with experimental data; finally the numerical optimization technique has been used to find out optimum milling factors. The optimal set of process parameters has also been incurred to maximize the MRR and minimize the surface roughness.

Keywords: vertical milling machine, aluminium alloy, MRR, surface roughness and RSM.

1. INTRODUCTION

The milling is the processing of machining flat and irregular surface by the workpiece feeding against a rotating cutter including a number of cutting edges. Milling process dwell of a motor driven spindle, which mounts and revolves the milling cutter and a alternative motion adjustable worktable and it's mounts and feeds the workpiece mateirals.

In the context of machining is any cutting tool is using to eliminate the material from the workpiece with the help of shear deformation [1]. Generally cutting tools is make harder than the material is cut, and the tool should be able to maintained the heat produced in the metal cutter processing and also this tool is generally have a specific geometry, with the clearance angles is designed so that the cutting edge can be contact with the workpiece is not the rest of the tool dragging on the workpiece surface. The cutter are generally made from maximum speed steel and coated carbide by means of cut through metals consist of mild steel and aluminium materials[2].

Paulo Davim *et al.* in [3] generated the impact of depth of cut, cutting speed and feed rate on surface roughness by developing Nuearl Netework models at the time of turning and free machining steel using cemented carbide tools. The relationship between tool life, surface roughness is removed [4].Ghani and Choudhury [5] Introduced a correspondent approach in this vibration signals are used to indicate tool wear and to difference the correlation between tool wear advance and surface roughness during turn periods. The experiments is conducted on nodular cast iron and ceramic tool, something that lead to very lower life of tool [6]. Some researchers are contribute of modeling and optimization of milling of RSM approach. So in this work tries to attempt that RSM approach for milling process.

2. METHODOLOGY

a) Experimental procedure

The experiment research is conducte on vertical milling machine and the material removal processes are shown in figure1. The work piece considered for this work is AA 6061 size was 100 X 100 X 5 mm each specimen to cut straight profile. Cutting operation carried out on work piece with straight profile the work piece was carefully clamped on work table [7]. The input factors considered as a feed rate of machine and depth of cut, spindle speed. Box-Behnken Design was selected for the three levels and 17 run experiments were carried out straight profile cut. The considered parameters ranges are the feed rate between (80 mm/min, 100mm/min and 120mm/min), depth of cut levels are within (0.5 mm, 1mm and 1.5mm) and spindle speed was (800 rpm, 1000 rpm and 1200 rpm). The 17 experimental runs were conducted based on Box-behnken approach. The collected experimental data were given in Table-2.

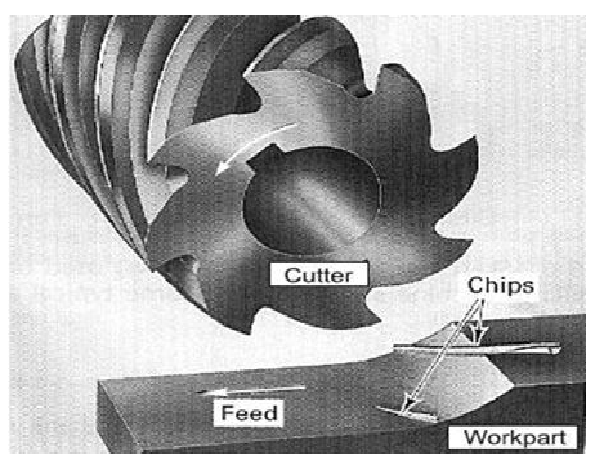

Figure-1. Mechanism of milling.

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b) Measurement of responses

To measure the Material removal rate for the following equation 1

$$MRR = Ap \times vc \times vf \quad (1)$$

Ap- Depth of cut,Vc- Cutting speed π d n/1000
Vf- Feed rate and the Surface roughness are measured by Mitutoyo Portable Surface Roughness Tester

3. RESULT AND DISCUSSION

a) RSM (Response surface methods)

RSM is consist ‘a collection of mathematical and statistical data. it’s used for the modeling and analysis of problems with a response of interest is impacted by many factors and the aim is to optimize the maximum response’[9]. Impact of material elimination rate and surface finishing, the considered parameters of this work is spindle speed, feed rate and depth of cutting, In order to model the interactions between those variables, the RSM is assumed equation 2:

$$R = b_0 + \sum_{i=1}^{2} b_i X_i + \sum_{i=1}^{2} b_{ii} X_{ii}^{2} + \sum_{i=1}^{2} \sum_{j=1,(i<j)}^{2} b_{ij} X_i X_j + \varepsilon \quad (2)$$

Table-1. Experimental data.

S. No	Feed rate (mm/ min)	Depth of cut (mm)	Spindle Speed (rpm)	MRR (mm^3/min)	Ra (µm)
1	100	1	1000	100000	4.342
2	100	0.5	800	40000	3.231
3	100	1	1000	100000	4.231
4	100	1.5	800	120000	4.231
5	120	0.5	1000	60000	4.762
6	100	0.5	1200	60000	3.975
7	80	1.5	1000	120000	5.012
8	120	1	1200	144000	4.214
9	80	0.5	1000	40000	4.821
10	120	1	800	96000	5.102
11	100	1	1000	100000	3.981
12	100	1	1000	100000	3.901
13	100	1.5	1200	180000	3.981
14	80	1	800	64000	4.012
15	120	1.5	1000	180000	5.002
16	80	1	1200	96000	4.219
17	100	1	1000	100000	4.873

b) Analysis of variance (ANOVA)

ANOVA is one of the statistical technique method used to find out the size of the data set[10]. The important factors of Analysis of variance tables are source of variance, sum of squares, degrees of freedom, mean square, F ratio, and the probability associated with the F ratio. The source of variance deals with independent factors. It’s is known as important factors (feed rate and spindle speed). A represented the spindle speed, B represented the depth of cut and C is feed rate.

The table II for MRR shows Model F-value is 2.82 so the model is significant one and also only a 3.16% chance so that the "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 mention model terms are significant. In this case B, C are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

Table-2. ANOVA table for MRR.

Source	Sum of Squares	do	Mean Square	F Value	p-value
Model	0.0858	9	0.0095	2.8157	0.0316
A	0.0029	1	0.0029	0.8679	0.3646
B	0.0482	1	0.0482	14.246	0.0015
C	0.0212	1	0.0212	6.2805	0.0227
AB	0.0027	1	0.0027	0.7974	0.3843
AC	0.0003	1	0.0003	0.0886	0.7696
BC	0.0003	1	0.0001	0.0040	0.9503
A^2	0.00025	1	0.0002	0.0744	0.7882
B^2	0.0007	1	0.0007	0.0233	0.8805
C^2	0.00257	1	0.0025	0.7595	0.3956
Residual	0.0575	17	0.0033		
LOF	0.0535	16	0.0033	0.8257	0.7126
Error	0.0040	1	0.0040		
Cur Tot	0.1433	26			

Table-3. ANOVA table for surface roughness.

Source	Sum of Sq	Do of	Mean Square	F Value	p-value
Model	0.1122	9	0.0124	4.8653	0.0025
A	0.0008	1	0.0008	0.0346	0.8545
B	0.0535	1	0.0535	20.889	0.0003
C	0.0366	1	0.0366	14.291	0.0015
AB	0.0075	1	0.0075	2.9249	0.1054
AC	0.0010	1	0.0010	0.3932	0.5389
BC	0.0003	1	0.0003	0.1189	0.7344
A^2	0.0009	1	0.0009	0.3706	0.5507
B^2	0.0010	1	0.0010	0.4254	0.5230
C^2	0.0016	1	0.0016	0.6244	0.4403
Residual	0.0435	17	0.0025		
LOF	0.0403	16	0.0025	0.7888	0.7232
Error	0.0032	1	0.0032		
Cur Tot	0.1558	26			

If there is many insignificant model The "Lack of Fit F-value" of 0.83 so Lack of Fit is not significant relative to the pure error. There is a 71.26% chance that a "Lack of Fit F-value" this large could occur due to noise.

The Table III for Ra Model F-value of 4.87 implies the model is significant. There is only a 0.25% chance that a "Model F-Value" this large could occur due

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to noise. Values of "Prob > F" less than 0.0500 indicate significant model terms. In this stage B, C are significant model terms. Values higher than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 0.79 implies the Lack of Fit is not significant relative to the pure error. There is a 72.32% chance that a "Lack of Fit F-value" this large could occur due to noise. And to develop the following Mathematical model are equations 3 & 4.

$$MRR = 2.38 - 7.74e^{-3}A \times 2.56e^{-3}B + 0.193 \times C + 1.2e^{-5}AB - 2e^{-4}AC + 2.05e^{-5}BC + 1.05e^{-5}A^2 + 1.5e^{-6}B^2 - 0.02C^2 \quad (3)$$

$$Ra = 2.5 - 0.0132A \times 1.39e^{-3}B + 0.247 \times C + 2^{-5}AB - 3.6e^{-4}AC + 9.7e^{-5}BC + 2.05e^{-5}A^2 + 5.6e^{-6}B^2 - 0.016C^2 \quad (4)$$

c) Response surface modeling graph

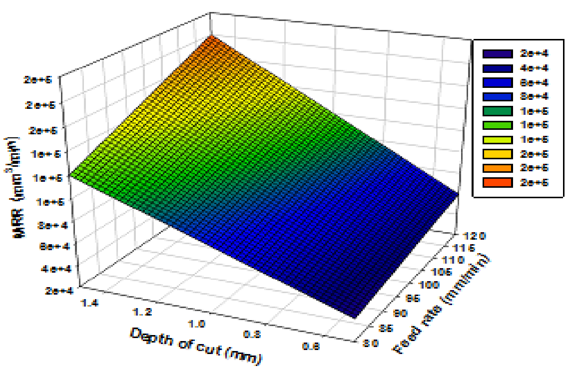

Figure-2. Effect on feed rate and depth of cut on MRR.

The Figure-2 express, firstly the MRR is low (range from 40000 to 100000 mm3/min) at entry level of the feed rate (80-120 mm/min) while high level of Depth of cut (0.5-1.5mm). MRR is gradually increased with respect to increase the DC and Feed rate. The MRR is maximum at the high level of Depth of cut (1.5mm).

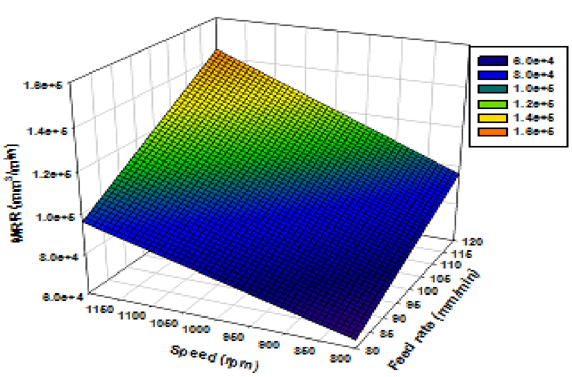

Figure-3. plots on effect of feed rate and speed on MRR.

The Figure-3 shows, initially the MRR is low (range from 64000 to 84000 mm3/min) at entry level of the feed rate (80-120 mm/min) while high level of cutting speed (1000-1200 rpm). MRR is gradually increased with respect to increase the speed and Feed rate. The MRR is maximum at the high level of Speed (1200 rpm).

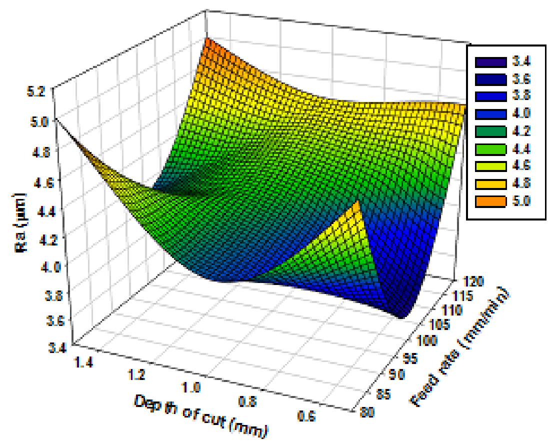

Figure 4 The plots on effect of feed rate and depth of cut on surface roughness.

The Figure express, firstly the SR is low (range from 3.9 to 4.5 micro meter) at entry level of the feed rate (80-120 mm/min) while high level of Depth of cut (0.5-1.5mm). SR is gradually increased with respect to increase the DC and Feed rate. The SR is maximum at the high level of Depth of cut (1.5mm).

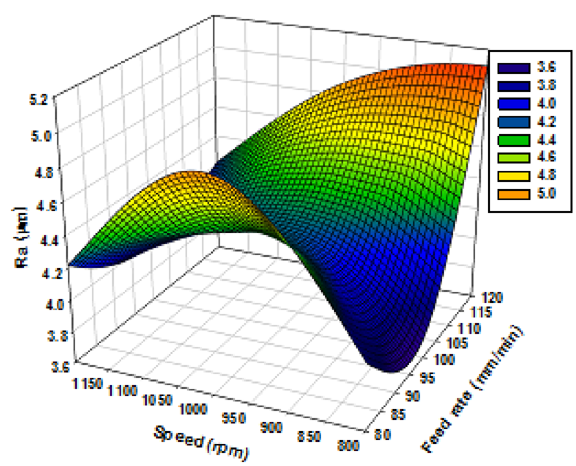

Figure-5. The plots on effect of feed rate and speed on surface roughness.

The Figure-5 shows, initially the SR is low (range from 3.7-4.5 micro meter) at entry level of the feed rate (80-120 mm/min) while high level of cutting speed (1000-1200 rpm). SR is gradually increased with respect to increase the speed and Feed rate. The SR is maximum at the high level of Speed (1200 rpm).

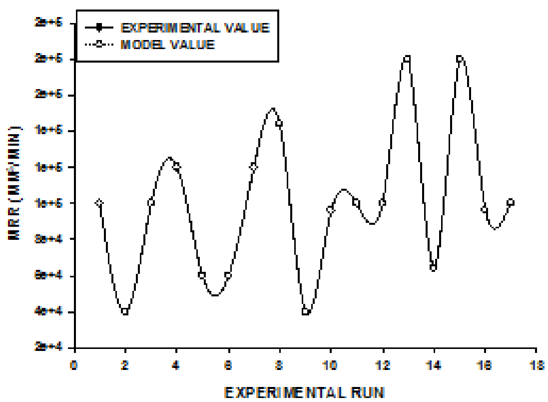

Figure-6. Experimental value vs model value on MRR.

d) Validation of experimental result

The Figure-6 and 7 are to validate the experimental value to develop the model value. The developed model values are good agreement with experimental value.

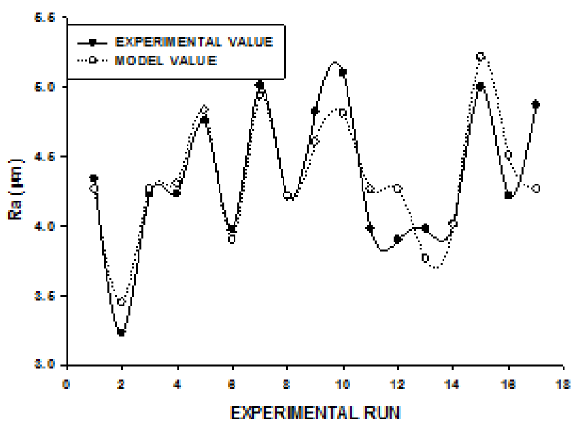

Figure-7. Experimental value vs model value on Ra.

4. CONCLUSIONS

This work presents the Findings of an Experimental Investigation on the impact of depth of cut, Cutting Speed and feed rate on the MRR and Surface roughness in machining on Aluminium alloy AA 6061 using milling machine. The Following Conclusion is drawn:

- The ANOVA Table for MRR and SR Shows the Model in Significant With the Probability of (F-Value).
- The Numerical Optimization is determined, and the Combination of Process Parameters is identified to achieve the minimum Surface value.
- The Feed rate and Cutting Speed plays a dominant Role in the Machining conditions of Aluminium alloys. This indicates that lower the feed rate and Small Cutting Speed and Depth of cut and large surface roughness Facilitate Rubbing Effect.
- The Interactive and Individual Effects on different factors with Responses is Studied. It is observed that Cutting Speed plays a dominant role in Surfaced roughness. And depth of cut plays dominant role in MRR.
- Contour Plots Can be Used graphically for Selection of Cutting Parameters and provide the Desired MRR and SR.
- The Minimum surface roughnessand maximum MRR is obtained from the Analysis, when the Process Parameters considered as Feed rate, Cutting Speed and depth of cut. It is possible to obtain Minimum Surface roughness and maximize the MRR Using the above Process Parameters.
- The Good Surface Quality with Minimum Surface roughness can be achieved when Feed rate and Cutting Speed are set to their Middle level.

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