Optimization Of Machining Parameters For Aluminium Alloy 6082 In Cnc End Milling

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ABSTRACT

The study aims at optimization of cutting parameters in CNC End milling of Aluminium Alloy 6082. CNC milling is a versatile and most widely used operation in present industry. Surface quality affects fatigue life of components and influence various mechanical properties and has received serious attention for many years. In this work, experiments are conducted to analyze the surface roughness using various machining parameters such as Spindle speed, feed rate and depth of cut . The data was used to develop surface roughness prediction models as a function of the machining parameters. In the present study, CNC machining centre with Cemented carbide end mill of 12mm diameter and 30° helix angle was used. A multiple regression analysis is used to correlate the relationship between the machining parameters and surface roughness. RS methodology was selected to optimize the surface roughness resulting minimum values of surface roughness and their respective optimal conditions. An attempt has been made to compare the results of Response surface methodology(RSM)with the Genetic Algorithm(GA).

Keywords: Aluminium alloy 6082, CNC End milling,GA, RSM ,Surface roughness.

1.0 INTRODUCTION

Milling is most widely used process in the machining of metals in present industry . Many parts are designed such that they must be processed on milling machines in at least one stage of their fabrication. CNC End milling is one of the most commonly used for its flexibility and versatility that allows manufacture of products in shorter time at reasonable cost and good finish.

Roughness is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion.

Considerable research taken place on surface finish for different situations. It is a common experience that at a low cutting speed, the increase of the contact area and the shear strength at sheared zone induces greater cutting forces and less surface finish. Therefore, the variation of the cutting forces at low speeds is a focal point and must be taken into consideration in the present work [2]. The RSM is practical, economical and relatively easy for use and it was used by lot of researchers for modeling machining processes [3 - 8]

Ahmed et.al [9] optimized cutting parameters such as cutting force, power, spindle speed using GA with a self organizing adaptive penalty strategy. M.Seeman et.al [10] studied the combined effects of cutting speed, feed rate, depth of cut and machining time on flank wear and surface roughness. In the present study, an attempt is made to optimize the machining parameters for lower surface roughness when end milling of aluminium alloy 6082 using Response Surface Methodology (RSM) and Genetic Algorithm (GA). The parameters are Spindle speed, feed rate , depth of cut and surface roughness. A second order mathematical model was developed by regression technique. This mathematical model was taken as objective function and was optimized using a RSM&GA approach to obtain the machining conditions for the minimum surface finish. Finally comparison of minimum surface roughness values obtained by both the optimization techniques used.

2.0 METHODOLOGY

In this work, Multiple linear regression analysis using MINITAB have been used for obtaining the relationship between response and machining parameters. The mathematical model have been used as objective function for optimization using RSM and GA

2.1 RSM Mathematical Formulation

Response surface methodology is a collection of statistical and mathematical methods that are useful for modeling and analyzing engineering problems. In this technique, the main objective is to optimize the response surface that is influenced by various process parameters. RSM also quantifies the relationship between the controllable input parameters and the obtained response surfaces. The data collected from the experiments was used to build a mathematical surface model using response surface methodology. The response surface methodology is a collection of mathematical and statistical techniques that are useful for modeling and analyzing problems in which response of interest is influenced by several variables, and the objective is to obtain the response. The following linear relationship could be considered for achieving this.

$$Y = f\,(\upsilon, .f, d) + \epsilon$$

Where v, f, d are speed, feed and depth of cut respectively of the machining processes, and ϵ is error which is normally distributed with mean=0according to observed response Y.

Let,

$$f\,(\upsilon, f, d) = \eta$$

The surface represented by ‘η’is called ‘response surface’.

The relationship between surface roughness and other independent variables is modeled as follows

$$R_a = C\upsilon^{k1} f^{k2} d^{k3}$$

Where ‘C’ is a constant and k_1, k_2, k_3 are parameters.

The above function can be represented in linear mathematical form as follows;

$$l_n R_a = C + k_1\, l_n\upsilon + k_2 l_n\, f + k_3 l_n d$$

The first-order linear model of the above equation canbe represented as follows;

$$Y_1 = y - \epsilon = b_0x_0 + b_1x_1 + b_2x_2 + b_3x_3$$

Where, Y1’ is the estimated response based on first-order equation and y is the measured surface roughness on a logarithmic scale x_1, x_2, x_3 . are logarithmic transformations of speed, feed and depth of cut respectively, ‘ϵ’ is the experimental error and b values are estimates of corresponding parameters.

The second-order model is as follows

$$Y'_2 = y - \epsilon = b_0x_0 + b_1x_1 + b_2x_2 + \ldots\ldots + b_{12}x_1\, x_2 + b_{23}x_2\, x_3 + b_{13}x_1\, x_3 + \ldots\ldots + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2$$

Where the parameters i.e. b_0, b_1, b_2, b_3 etc are to be estimated..

Y'_2 is the estimated response based on second-order equation [5].

2.2 Genetic Algorithm (GA)

Genetic Algorithms are search algorithms for optimization, based on the mechanics of natural selection and geneties [8,10]. The power of these algorithms is derived from a very simple heuristic assumption that the best solution will be found in the regions of solution space containing high proposition of good solution, and that these regions can be identified by judicious and robust sampling of the solution space.

The mechanics of Genetic Algorithms is simple, involving copying of binary strings and the swapping of the binary strings. The simplicity of operation and computational efficiency are the two main attractions of the Genetic Algorithm approach. The computations are carried out in three stages to get a result in one generation or iteration. The three stages are (a) Reproduction (b) Cross-over (c) Mutation [11,12]. Fig.2.1 shows the various steps involved in the G.A. for Optimization.

2.2.1. Reproduction

This is the first of the genetic operators. It is a process in which copies of the strings are copied into a separate string called the ‘mating pool’, in proportion to their fitness vaules. This implies that strings with higher fitness values will have a higher probability of contributing more strings as the search progresses.

2.2.3. Crossover

This operator, second among the genetic operator, is mostly responsible for the progress of the search. It swaps the parent strings partially, causing offspring to be generated. In this, a crossover site along the length of the string is selected randomly, and the portions of the strings beyond the crossover site are swapped.

2.2.3. Mutation

It is one of last GA operators, this is the occasional random alteration (with a small probability) of the value of a string position. In binary strings, this simply means changing 1 to 0, or vice versa.

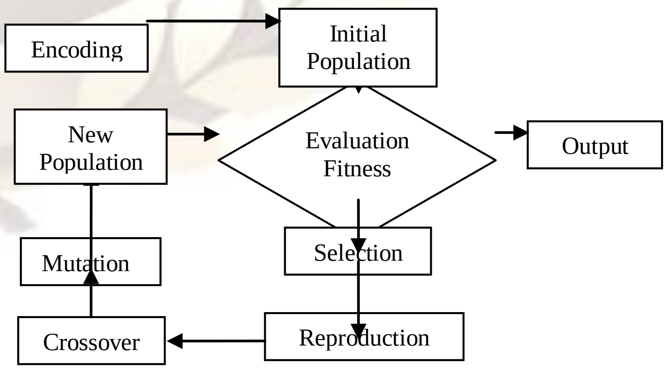

Fig.2.1

3. EXPERIMENTAL PROCEDURE

3.1 Plan of Experiments

An important stage of RS model generation by RSM is the planning of experiments.

The design of experiments technique is a very powerful tool, which permits us to carry out the modeling and analysis of the influence of process variables on the response variables.The response variable is an unknown function of the process variables, which are known as design factors. There are a large number of factors that can be considered for machining of a particular material in end milling. In this study, cutting experiments are planned using statistical three-level full factorial experimental design. Cutting experiments are conducted considering three cutting parameters: Spindle Speed (rpm), Feed rate (mm/min), Depth of Cut (mm) and Overall $3^3 = 27$ experiments were carried out. Table 3.1 indicates the values of various parameters used for experiments.

Table3. 1 : Experimental design

	LEVEL 1	LEVEL2	LEVEL 3
Spindle speed rpm	2000	2500	3000
Feed rate , mm/min	1000	1500	2000
Depth of cut , mm	0.2	0.5	0.8

3.2 Material and Tool

In the present study, Aluminium alloy 6082 was used with the following chemical composition as shown in Table3. 2

Table3. 2 : Chemical composition of work material

Alloy 6082	Weight %
Al	Bal
Si	0.7-1.3
Fe	0.50 max
Cu	0.10 max
Mn	0.40-1.00
Cr	0.25 max
Mg	0.06-1.20
Zn	0.20 max
Ti	0.10 max
Others Each	0.05 max

Fig.3. 1 : CNC Milling Machine – Vertical Machining Centre

The tests were performed on a vertical CNC machining center with make of 'Bharat Fritz Werner Ltd.' and model being Agni BMV 45 TC-24 4-Axis Vertical Machining Center. Here 45 stand for maximum translation along Y axis by 45 cms. TC-24 stands for Tool Changer, 24 tools in the disc type tool magazine. 4-Axis stands for movement along 4 different axis viz. translation along X,Y and Z axis and rotation about X-Axis.

3.3 Surface Roughness Tester:

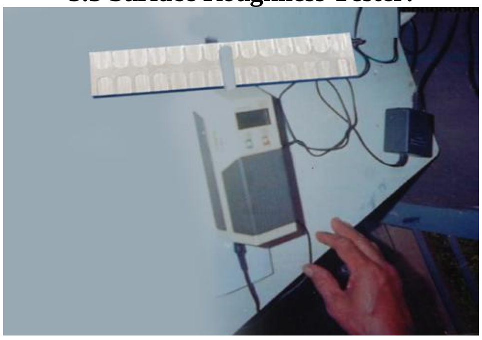

Fig. 3.2 Surface Roughness Tester

Roughness measurement was done using a portable stylus type talysurf, surface roughness tester SJ-201P. The talysurf was set to a cut-off length of 2.5 mm, traverse speed 0.5 mm/sec and 4 mm evaluation length. Roughnessmeasurements, in the transverse direction,on the workpieces were repeated three times and average of three measurements of surface roughnessparameter values was recorded. The measured profile was digitized and processed through the dedicated advanced surface finish analysis software for evaluation of the roughness parameters.

4. RESULTS AND DISCUSSIONS .

The complete results from the 27 machining trails for Aluminium alloy6082 performed as per the experimental plan.Table 4.1 shows the values of 27 experimental setups
with the measured surface roughness(Ra) values.

Table4.1: Machining Parameters with measured Ra values

S.no	Spindle Speed in rpm	Feed rate in mm/min	Depth of cut in mm	Ra in microns
1	2000	1000	0.8	1.379
2	2000	1500	0.8	1.4
3	2000	2000	0.8	1.46
4	2500	1000	0.8	1.34
5	2500	1500	0.8	1.39
6	2500	2000	0.8	1.417
7	3000	1000	0.8	1.326
8	3000	1500	0.8	1.351
9	3000	2000	0.8	1.38
10	2000	1000	0.5	1.32
11	2000	1500	0.5	1.34
12	2000	2000	0.5	1.359
13	2500	1000	0.5	1.318
14	2500	1500	0.5	1.338
15	2500	2000	0.5	1.349
16	3000	1000	0.5	1.27
17	3000	1500	0.5	1.305
18	3000	2000	0.5	1.344
19	2000	1000	0.2	1.24
20	2000	1500	0.2	1.27
21	2000	2000	0.2	1.326
22	2500	1000	0.2	1.216
23	2500	1500	0.2	1.264
24	2500	2000	0.2	1.297
25	3000	1000	0.2	1.175
26	3000	1500	0.2	1.251
27	3000	2000	0.2	1.24

The Mathematical relationship between responses and Machining parameters was established using the Multiple regression analysis. In the present study, The correlation between the machining parameters Spindle speed, feed rate, depth of cut and surface roughnessare established.The multiple regression model was obtained using statistical software MINITAB.

The regression equation obtained from the analysis is given in equation (4.1) below.

Regression analysis shows 94.4% of closeness with experimental data as shown in Table 4.2

Table4: Summary of regression analysis of Aluminium alloy 6082

Responses	S value	R – Sq	R – Sq (adj)
	0.01538	96.4%	94.4%

Ra=0.994923+speed*9.51667*10^{-5} +feed*0.000123056+Depth of cut*0.350123-speed*speed* 2.71111*10^{-8}-feed*feed*1.37778*10^{-8}-Depth of cut*Depth of cut *0.101235-speed*feed * 4.33333*10^{-9}-speed*Depth of cut *6.66667*10^{-6}-feed*Depth of cut *1.11111*10^{-5} --- - Eq. (4.1)

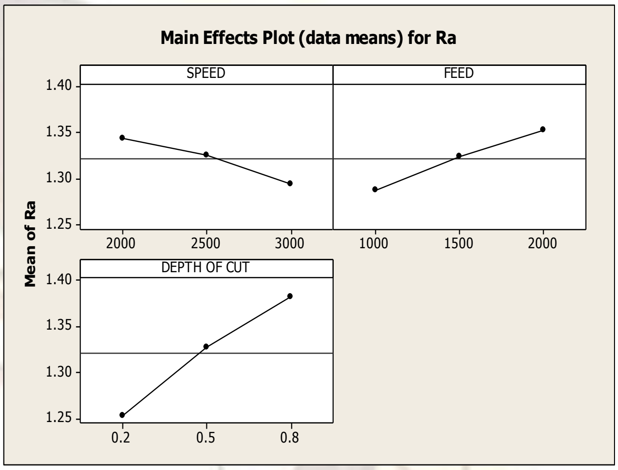

Fig.4.1 : Main effects plot for aluminium alloy 6082

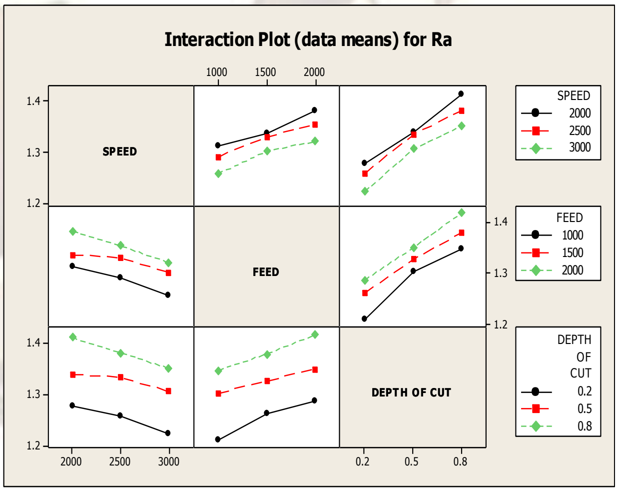

Fig.4.2 : Interaction effects plot for aluminium alloy 6082

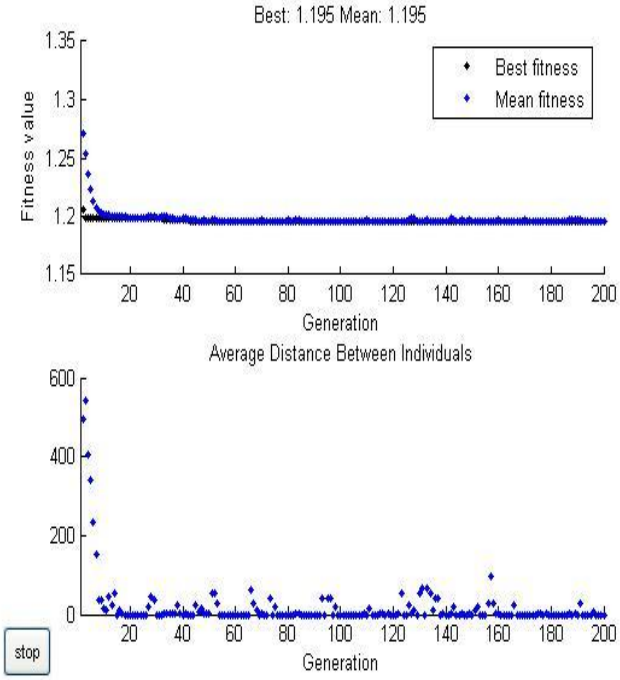

Fig.4.3 : The results of GA analysis

The main effects of various machining parameters are read from the Main effects plot shown in fig. 4.1 and the interaction effects of various parameters are given in fig.4

The fig.4.3 shows the results of GA analysis , how the result is converging towards the optimum values. Reffering to Fig.4.1, for alluminium alloy 6082 the following discussions have been made. The surface roughness decrease with the increasing spindle speed. The surface finish deteriorates when the feed rate and depth of cut are increasing to a maximum value.

Table 4.3 : Optimum values obtained from RSM and GA

S.No	parameters	Optimum values obtained from	
		RSM	GA
1	Spindle speed (rpm)	3000	2997.64729
2	Feed rate (mm/min)	1000	1005.94134
3	Depth of Cut (mm)	0.2	0.20862
4	Ra (microns)	1.192	1.195

It was observed from Table 4.3 that the roughness values obtained from RSM is better than the results obtained from GA.

5.CONCLUSIONS

- In the present study, the best combination of cutting perameters have been found to provide the lowest surface roughness for end milling of aluminium alloy 6082 using cemented carbide tooling. From this study it is observed that the surface finish detoriorates with the decrease in the spindle speed as well as with the increase in both the feed rate and depth of cut.
- The Regression analysis was conducted to develope mathematical model. The Regression analysis shows closeness of 94.4% with experimental data.
- The optimal surface roughness values estimated by RSM technique is 1.192 microns with the machning conditions of spindle speed = 3000 rpm, feed rate = 1000 mm/min, and depth of cut = 0.2 mm and for GA is 1.195 microns with spindle speed = 2997.64729 rpm, feed rate = 1005.94134 mm/min and depth of cut = 0.20862mm.
- RSM found successful technique to perfrom analysis of surface roughness with respect to various combinations of machining parameters (spindle speed, feed rate, & depth of cut) when compared to GA.
- The accuracy of the RS model was verified with the experimental measurement. The verifying experiment has shown that the predicted value agrees with the experimental evidence.
- With the model equations obtained, a designer can subsequently select the best combinations of design varaiables for achieving optimum surface roughness. This eventually reduces the machining time and improves tool life.

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