Optimization of CNC Turning Process Parameters on ALUMINIUM 6061 Using Genetic Algorithm

N. Zeelan Basha, G. Mahesh, N. Muthuprakash

Abstract : This paper presents the effect of process parameter in turning operation to predict surface roughness. Application of alumunium 6061 can be found in many manufacturing industries such as aircraft and aerospace components, marine fittings, transport, bicycle frames, camera lenses, drive, shafts, electrical fittings and connectors, brake components, valves, couplings. But some of the limitations during machining of aluminum 6061 are lower strength at elevated temperatures and limited formability affects quality of desired output. A lot of parameters that affect the turning operation are vibration, tool wear, surface roughness etc. Among this surface roughness plays a major role which affects the quality in the manufacturing process. This paper presents the effect of process parameter by considering the Spindle speed, Feed rate and Depth of cut. The main objective of this paper is to predict the surface roughness. Aluminium 6061 is taken into a consideration, machining is done by using coated carbide tool. A second order mathematical model is developed using regression technique of Box-Behnken of Response Surface Methodology (RSM) in design expert software 8.0 and optimization carried out by using genetic algorithm in matlab8.0. This study attempts the application of genetic algorithm to find the optimal solution of the cutting conditions.

Index Terms*: *Surface Roughness, Genetic Algorithm, Optimization, CNC Turning Centre.

I. INTRODUCTION

In machining operation, Surface roughness is an important factor which affects the work piece and tool. Surface roughness is primarily dependent on the production process. A lot of parameters that affect the surface roughness such as spindle speed, feed rate, depth of cut, cutting speed, type of lubrication used, tool angle, tool height, properties of tool used for cutting operation etc. In manufacturing

Industries turning is one of the most widely used metal removing process. As for as the literature reviewed there is a research gap identified and literatures is very low by considering Aluminum 6061 as a base metal. Machining with CNC requires that an operator select the process parameters such as feed rate, spindle speed and depth of cut, thus the process still depends on knowledge and experience. Furthermore, with the advances of computer-controlled machine tools, more precise predictive models are required.

Response surface methodology (RSM) is a combination of statistical and optimization methods. RSM works by applying different designed experiments to obtain a polynomial model of the process keeping the independent variable as the system output which is minimized.

A comprehensive algorithm of the calculations involved. These approaches comprise a systematic method of scheduling experiments as well as gathering and analyzing records with a near-optimum use of resources. The most widely employed methodologies for surface roughness prediction in terms of machining parameters are the RSM. The various forms of regression analysis concentrate on using existing data to predict future results. It is used to examine the relationship among several factors and the results. Regression is applied to create models to predict the results when combinations of factors interact under various conditions. It is one of the most widely used statistical tools because it provides a simple method of establishing a functional relationship among variables. The relationship is expressed in the form of an equation connecting the response or dependent variable (y),and one or more independent variables,$x_1, x_2, x_3, \ldots\ldots. x_n$.

The genetic algorithm (GA) is a population-based search optimization technique. In general, the fittest individuals of any population tend to reproduce and survive to the next generation, thus improving successive generations. However, inferior individuals can, by chance, survive and also reproduce. Genetic algorithms have been shown to solve linear and nonlinear problems by exploring all regions of the state space and exponentially exploiting promising areas through mutation, crossover and selection operations applied to individuals in the population.

II. LITERATURE REVIEW

[1] An experiment has been conducted to observe the significance of process parameters and the influence of the radial rake angle of the tool in end mill cutter. A mathematical model has been developed to predict surface roughness in terms of machining parameters such as spindle speed, feed rate, radial, radial depth of cut, and rake angle of cutting tool. The second-order mathematical models, in terms of the machining parameters, have been developed using Response surface methodology (RSM). The experiment is conducted at aluminum 6063 by using HSS end mill cutter, the surface roughness.

[2] The influence of machining process parameters such as cutting speed, feed rate, and depth of cut is taken to an consideration and the optimization is carried out to optimize material removal rate and surface roughness. The optimum combination of input parameters for maximization of material removal rate is found to be Cutting speed 79.99m/min, Feed rate 0.25mm/rev, Depth of cut 0.1mm and best fitness value is 2122.23 mm3/min. and the optimum combination of input parameters for minimization of surface roughness found to be

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cutting speed 79.9m/min, feed rate 0.15mm/rev, depth of cut 0.1mm and Best fitness for minimization of surface roughness is 0.69 µm.

[5] Response surface methodology (RSM) and genetic algorithm (GA) is used to determine the optimum cutting conditions leading to minimum surface roughness in milling of mold surfaces. RSM is utilized to create an efficient analytical model for surface roughness in terms of cutting parameters: Feed rate, Cutting speed, Axial depth of cut, Radial depth of cut and Machining tolerance. RSM model is further interfaced with the GA to optimize the cutting conditions for desired surface roughness. The GA reduces the surface roughness value in the mold cavity from 0.412µm to 0.375µm corresponding to about 10% improvement.

[9] The effects of Cutting speed, Feed rate, Work piece hardness and Depth of cut on surface roughness and cutting force components in the hard turning were experimentally investigated. Cutting speed, Feed rate, hardness and depth of cut) and three-level fractional experiment designs completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for surface roughness and cutting force components were developed using the response surface methodology (RSM). the ranges for best cutting conditions are proposed for serial industrial production are feed force (Fa) and the cutting force (Fv) are strongly influenced by the depth of cut, (56.77%) and (31.50%) respectively. On the opposite, the cutting speed has a very small influence (0.14%). The best surface roughness was achieved at the lower feed rate and the highest cutting speed.

[12] Two independent data sets were obtained on the basis of measurement: training data set and testing data set. Spindle speed, Feed rate, Depth of cut, and vibrations are used as independent input variables (parameters), while surface roughness as dependent output variable. On the basis of training data set, different models for surface roughness were developed by genetic programming. Accuracy of the best model was proved with the testing data. It was established that the surface roughness is most influenced by the feed rate, whereas the vibrations increase the prediction accuracy.

[13] In order to find out the effect of tool geometry parameters on the surface roughness during turning, response surface methodology (RSM) was used and a prediction model was developed related to average surface roughness (Ra) using experimental data. The results indicated that the tool nose radius was the dominant factor on the surface roughness. In addition, a good agreement between the predicted and measured surface roughness was observed. Therefore, the developed model can be effectively used to predict the surface roughness on the machining of AISI 1040 steel within 95% confidence intervals ranges of parameters. Tool nose radius is the most significant factor on surface roughness with 51.45% contribution in the total variability of model. Also, approach angle and rake angle are significant factors on surface roughness with 18.24% and 17.74% contribution in the total variability of model. Using response optimization show that the optimal combination of machining parameters are (0.4 mm, 60°, -3°) for tool nose radius, approach angle and rake angle.

III. METHODOLOGY

A. For Experimental Work

i) The material and tool inserts are selected based on the problem identification study.
ii) Identifying different ranges of input parameters and their levels.
iii) Measuring surface roughness (Ra) using surface roughness tester SJ-210.

B. For Theoretical Work

i) Formation of regression equation using design- expert 8.0 software.
ii) Calculation of predicted readings of surface roughness (Ra)

C. For Analysis Work

i) Checking the adequacy of the models developed
ii) Comparing the optimization results with the experimental results and finding out the percentage error between them.
iii) Presenting the effects of the process parameters on the mechanical properties in graphical form and analyzing the results.
iv) Validation of results.

IV. EXPERIMENTAL DETAILS

A. Work Piece Material

The work material used was aluminium 6061 and its chemical composition and hardness are tested and hardness value is found to be 43 HRC. The table below shows the chemical composition of aluminium 6061.

Table 1 Chemical composition for alumunium 6061

Weight (%)	Al 6061
Al	Bal
Si	0.40-0.80
Fe	0.70 max
Cu	0.15-0.40
Mn	0.15
Mg	0.8-1.2
Cr	0.04-0.35
Zn	0.25 max
Ti	0.15 max
Others each	0.05 max
Others each	0.15 max

B.Cutting Tool

AK10 Carbide Inserts for Turning Ground and Polished for Aluminium Uni-tip was used for turning.

Figure- 1 cutting tool AK10 Carbide insert

C.Experimental Set Up And Cutting Conditions

Machining process was carried out in CNC turning centre. The machining process involved various cutting parameters such as cutting speed, depth of cut, feed rate. The surface roughness (Ra) were taken on surface roughness Tester SJ-210.Three measurements of surface roughness were obtained at different surface of machined work piece and average value is used in the further analysis.

D. Surface Roughness Tester Sj-210

The Surface roughness tester used for measuring surface roughness (Ra) in this experimental analysis is given below

Figure- 2 Surface roughness Tester SJ-210

E.Cnc Turning Centre

The CNC turning centre used for machining Purpose shown below along with specification,

Figure- 3 CNC XL Turning centre

Specification of Turning Centre (fig.3):
Control system-fanuc emulated
Spindle power-1Hp
Spindle speed-100 to 3000 rpm
Max. Turning dia-32mm
Rapid traverse rate-1.2m/min

F. Combination Of Parameters And Their Levels

In this experimental analysis the parameters has been conducted in three levels -1, 0, 1

Table: 2.Values of three factorial levels

Cutting parameter	Units	Levels		
		-1	0	1
spindle speed	rpm	1000	1500	2000
Feed rate	mm/min	0.04	0.08	0.12
Depth of cut	mm	0.6	0.7	0.8

G. EXPERIMENTAL VALUES

The design of experiment developed in box benkhen of response surface methodology used to conduct the experiments and develop the mathematical model for prediction of surface roughness (Ra).

1) Input parameters
   X_1 -spindle speed (rpm)
   X_2 -Feed rate (mm/min)
   X_3-Depth of cut (mm)
2) Output parameters
   Y_1 -surface roughness Ra (µm)

Table: 3 Design Matrixes and Response

Run	Input Parameters			Output Parameters
	X_1	X_2	X_3	Y_1
1	1500	0.08	0.6	0.696
2	1500	0.06	0.7	0.687
3	1500	0.06	0.7	0.684
4	2000	0.06	0.6	0.628
5	1500	0.04	0.8	0.683
6	1500	0.06	0.7	0.688
7	2000	0.08	0.7	0.720
8	1000	0.08	0.7	0.720
9	1000	0.04	0.7	0.760
10	1500	0.04	0.6	0.670
11	1500	0.06	0.7	0.673
12	2000	0.04	0.7	0.650
13	1000	0.06	0.6	0.681
14	1500	0.06	0.7	0.672
15	1500	0.08	0.8	0.686
16	2000	0.06	0.8	0.700
17	1000	0.06	0.8	0.682

H. Regression Equations

Regression equations were formed using design expert 8.0 software for surface roughness Ra (**Y**)

The regression equation for Surface Roughness Ra (**Y**) is

$$Y=+0.53925-5.37950E-004*X_1-7.39875*X_2+2.13100*X_3+2.75000E003*X_1X_2+2.55000E-004*X_1X_3-2.87500*X_2X_3+5.14000E-008*X_1^2+47.12500*X_2^2-1.59000*X_3^2$$

V. RESULTS AND DISCUSSIONS

Best fitness for minimization of surface Roughness is shown in fig.4 using genetic algorithm tool.

Considering Population 100, Current generation 52
The Optimization values for cutting parameters are
Spindle speed= 1999.999rpm,
Feed rate =0.041mm/min
Depth of cut =0.6mm

Best fitness for minimization of surface Roughness is 0.611µm

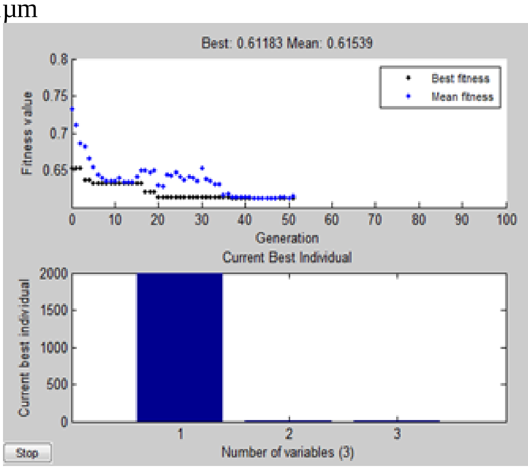

Figure- 4 graph for surface roughness

A.Confirmatory Process

Table: 4.Confirmatory Test Ra (E vs D)

sl.no	parameters	values
A	Spindle speed (rpm)	1999.999
B	Feed rate (mm/min)	0.041
C	Depth of cut(mm)	0.6
D	Predicted-Ra(µm) found from genetic algorithm	0.611
E	Experimental-Ra (µm)	0.613
F	G=((E-D)/E)*100	0.32
G	ERROR %	0.32

VI.CONCLUSION

This investigation attempts the application of genetic algorithm and found that optimal solution of the cutting conditions achieved on spindle speed (rpm)= 1999.999, feed rate (mm/min)= 0.041 and depth of cut (mm)=0.6 for giving the minimum value of surface roughness(µm)=0.611 using genetic algorithm. The confirmatory test was conducted and found that the percentage of error within 0.32%.

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