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Modelling and Analysis of Tool life on CNC Turning of Auminiumalloy 6063 using Tungsten Carbide Tools : Application of Taguchi Technique

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ABSTRACT

In the present study, investigate the influence of spindle speed (N), feed rate (f) and depth of cut (d) on tool life during CNC Turning of Aluminium alloy 6063 using Carbide Tools. Experiments were conducted through the Taguchi's Design of Experiments (DOE). Statistical model based on second order polynomial equation was developed for tool life. Analysis of variance (ANOVA) was carried out to identify the significant factors affecting the tool life. The surface plots were generated to study the effect of process parameters as well as their interactions.

KEYWORDS:*CNC turning, Carbide tool, Tool Life, Taguchi method, Mathematical model, Anova.*

I. INTRODUCTION

Traditionally, the machinability of materials involves tool life, cutting forces, productivity or chip formation, with less attention paid to particle emission. Turning is one such machining process which is most commonly used in industry because of its ability to have faster material removal at the same time produces reasonably good surface finish quality. During turning process, higher values of cutting parameters offer opportunities for increasing output but it also involves a greater risk of deterioration of surface quality and tool life, therefore cutting speed and feed rate are two very important parameters to achieve optimum cutting conditions [1].

V. Devkumaret et.al., [2] investigated the optimal cutting conditions for attaining the better surface roughness using the mathematical modeling and analysis of machining response and tool wear in the turning of aluminum alloy 6061. There was process parameters such as spindle speed, depth of cut and feed rate used to determine the quality of surface roughness. chandrashekar et al [3] optimized the machining parameters speed, feed, depth of cut, nose radius in turning of Al 6063 T6 in CNC machine through design of experiments by taguchi method. P. Jayaraman et.al., [4] researched on multi response optimization of machining parameters such as cutting speed, feed rate, and depth of cut in turning of AA 6063 T6 using grey relational analysis in Taguchi method.

Table.1 Chemical composition of the aluminium alloy 6063

Element	Si (%)	Fe (%)	Cu (%)	Mn (%)	Mg (%)	Zn (%)	Ti (%)	Cr (%)	Aluminium
Weights	0.2-0.6	0.0-0.35	0.0-0.10	0.0-0.10	0.45-0.9	0.0-0.1	0.0-0.1	0.1max	balance

H.M. Samashekara [5] has developed regression model during machining of Al 6351-T6 Aluminium alloy with the help of uncoated carbide insert to analyze the combination of machining parameter(speed, feed, depth of cut) for better performance within selected range of machining parameter. Himanshuborade et al.,[6] optimizing the process parameter in CNC turning of Aluminium 7068 alloy using the Taguchi method with the use of multi-response criteria for grey relational analysis. B.Radhakrishnan et al.,[7] optimizing the surface roughness obtained by turning process in CNC machine using various parameters.

In this work, effects of process parameters on tool life in CNC turning of aluminium alloy 6063 by carbide tools are evaluated. A second order quadratic model is developed for predicting the tool life in CNC Turning of aluminium alloy 6063 by response surface methodology. The predicted and measured values are fairly close to each other. Their proximity to each other indicates that the developed model can be effectively used to predict the tool life in CNC Turning of aluminium alloy 6063.

II. Experimental Details

The experiments were planned using Taguchi's orthogonal array in the design of experiments (DoE), which helps in reducing the number of experiments. The three process parameters selected in the present investigation were spindle speed, feed rate and depth of cut.

The machining was done on "LOKESH TL20" CNC turning machine using carbide tool. The parameters and their levels were selected is given in the Table.2. The dimension of work specimen was 25 mm diameter and 100 mm length. Experimental design using L27 orthogonal array and results are listed in Table 3.

The tool life was calculated using the formulae.

Tool life $=\left(\frac{80}{V \times f^{n1} \times d^{n2}}\right)^{\left(\frac{1}{n}\right)}$ in min -------------------- (1)

Where,

V = Cutting speed in m/min

f = Feed in mm/rev

d = Depth of cut in mm

T = Tool life in min

N= Tool constant for Tungsten carbide– 0.33(from toolmanufacturer's data book)

n1= feed exponent constant – 0.6 (from toolmanufacturer's data book)

n2 =depth of cut exponent constant- 0.15 (from toolmanufacturer's data book)

C= constant- 80 (from tool manufacturer's databook)

Table.2 Experimental parameters and their levels

No	Factor	Unit	Notation	Levels		
				(-1)	0	(+1)
1	Spindle speed	RPM	*N*	1000	1500	2000
2	Feed rate	mm/rev	*f*	0.1	0.15	0.2
3	Depth of cut	mm	*d*	0.5	1	1.5

III. RESULTS AND DISCUSSION

Tool life plays a predominant role in determining the machining accuracy and control the machining cost. The study of tool life characteristics of aluminium alloy 6063 dependent on many factors, it is more influenced by the process parameters like spindle speed, feed rate and depth of cut, etc., for a given machine tool and work piece set-up. The influence of different process parameters in CNC Turning of aluminium alloy 6063 can be studied by using response graph and response table. The influence of process parameters on tool life is shown in Figure 1.

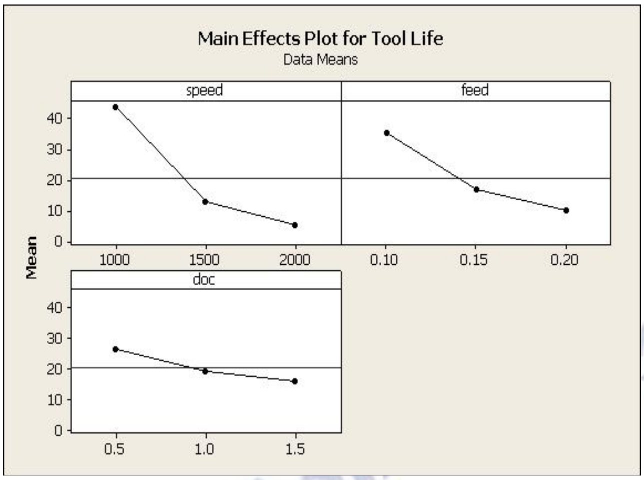

FIG 1: Effect plot for Tool life.

The observed tool life increases at low spindle speed as compared to the high spindle speed. Also, tool life increases at low feed rate when compared to the high feed rate. The effect of depth of cut on CNC turning of aluminium alloy 6063 is less on tool life. The response table for tool life shows the effect of different process parameters, which is shown in Table. 4. From the table, it can be found that the spindle speed is the main parameters which affect the tool life followed by feed rate and depth of cut.

The experimental values are analyzed using response surface analysis and the following relation has been established for Tool life in uncoded units as:

tool life = 431.4- 0.2686 speed- 1767 feed
- 74.00depth+ 0.000047 speed*speed
+ 2292 feed*feed+ 7.80 depth*depth
+ 0.4676 speed*feed+ 0.01935 speed*depth
+ 126.8 feed*depth --------------------------(2)

A result of ANOVA for the response function Tool life is presented in Table 5. This analysis is carried out for a level of significance of 5% i.e., for a level of confidence of 95%. From the table, it is apparent that, the F calculated value is greater than theF-table value ($F_{0.05,}$ 9, 17= 2.49) and hence thesecond order response function developed is quite adequate.

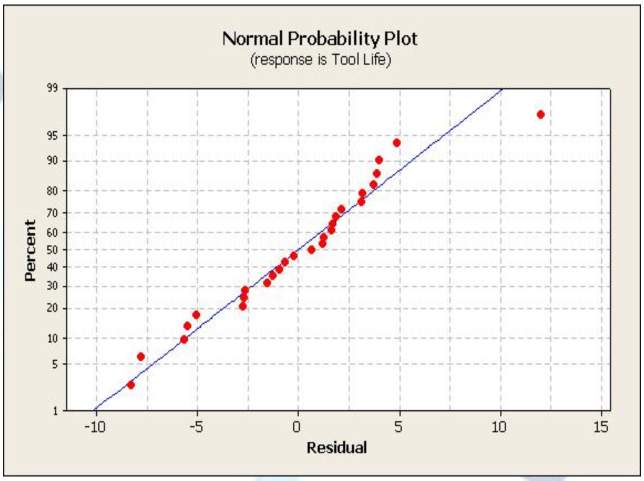

FIG 2: Normal Probability plot for Tool life.

The plot of normal probability of the residual, the plots of the residuals versus the fitted values for tool life is shown in figure. 2. From figure 2, it is evident that the data are spread roughly along the straight line. Hence it is concluded that the data are normally distributed. Hence, the developed model is significant & adequate.

Surface plots were drawn for different combination of process parameters, which is shown in figure. 3. These response surfaces can help in the prediction of the toll life at any zone of

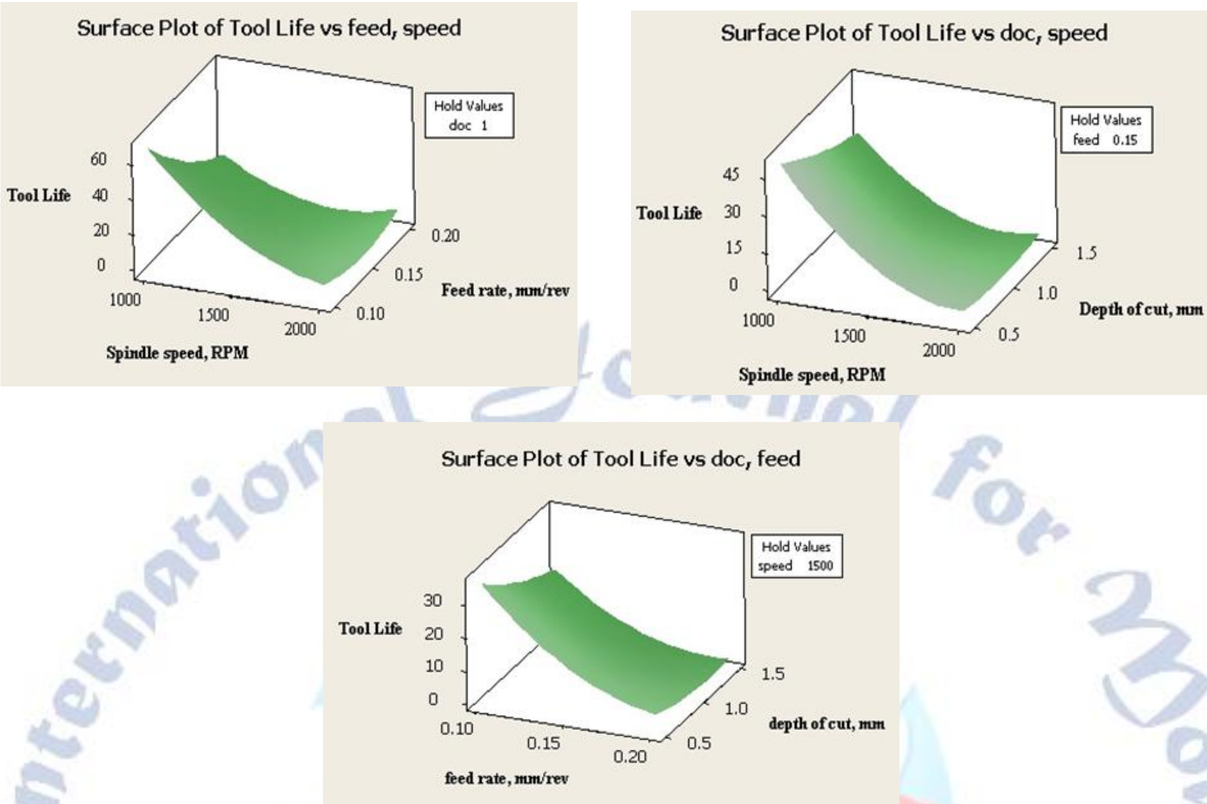

FIG: 3 Surface plots for Tool life (T), mins

Table.3 Experimental design using L_{27} orthogonal array and results

Sl.No.	Spindle speed (N), RPM	Feed rate (f), mm/rev	Depth of cut (d), mm	Tool Life (T), mins
1	1000	0.1	0.5	95.48
2	1000	0.1	1	69.68
3	1000	0.1	1.5	57.95
4	1000	0.15	0.5	44.68
5	1000	0.15	1	33.34
6	1000	0.15	1.5	27.73
7	1000	0.2	0.5	27.08
8	1000	0.2	1	19.76
9	1000	0.2	1.5	16.43
10	1500	0.1	0.5	27.95
11	1500	0.1	1	20.39
12	1500	0.1	1.5	16.96
13	1500	0.15	0.5	13.37
14	1500	0.15	1	9.76
15	1500	0.15	1.5	8.11
16	1500	0.2	0.5	7.92
17	1500	0.2	1	5.78
18	1500	0.2	1.5	4.81
19	2000	0.1	0.5	11.69
20	2000	0.1	1	8.53
21	2000	0.1	1.5	7.09
22	2000	0.15	0.5	5.59
23	2000	0.15	1	4.08
24	2000	0.15	1.5	3.39
25	2000	0.2	0.5	3.31
26	2000	0.2	1	2.42
27	2000	0.2	1.5	2.01

Table.4 Response table for Tool life

Level	Spindle speed, N (RPM)	Feed rate, f (mm/rev)	Depth of cut, d (mm)
1	31.46	27.60	24.18
2	20.78	21.20	21.44
3	13.21	16.66	19.84
Delta	18.24	10.95	4.34
Rank	**1**	**2**	**3**

Table 5: ANOVA for the response function of the Tool life

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	*F* value	p value
Regression	9	12969.2	1441.02	49.53	0.000
Residual Error	17	494.6	29.09		
Total	26	13463.8			

the experimental domain. It is clear from these figures that the tool life increases with the decrease of spindle speed and it decreases with the decreases of feed rate. Figure 3 shows the experimental values and their corresponding predicted values through Eq. (1). From the analysis of figure, it can be observed that the predicted values were very close to the experimental results.

IV. CONCLUSION

The tool life in the CNC turning process has been measured for machining of aluminium alloy 6063 under different cutting conditions with a carbide tools using L_{27} Taguchi's orthogonal array. Based on the experimental and analytical results the following conclusions are drawn.

1. The developed second-order response surface model can be used to calculate the tool life of tungsten carbide tool at different cutting conditions with the chosen range with 95% confidence intervals. Using such model, one can obtain remarkable savings in time and cost.

2. From the results, it can be asserted that low spindle speed, low feed rate and moderate depth of cut are preferred for machining of aluminium alloy 6063.

3. The Spindle speed is the dominant parameter which affects the tool life of aluminium alloy 6063 followed by feed rate. Depth of cut shows a minimal effect on tool life compared to other process parameters.

4.From the developed mathematical model, the optimal machining parametric combination, i.e., spindle speed (N) 1000 rpm, feed rate (f) 0.10 mm/rev and depth of cut (d) 0.50 mm was found out to achieve the maximum tool life as 95.48 mins.

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