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Implementation of Taguchi methodology to Optimization of CNC end milling process parameters of AL6351 –T6

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Abstract: *In this paper we have study on CNC end milling, influence of various machining parameters like, tool feed (mm/min), tool speed (rpm), tool diameter (mm) and depth of cut (mm). In the present study, experiments are conducted on AL 6351 –T6 material with three levels and four factors to optimize process parameter and surface roughness. An L9 (3*4) Taguchi standard orthogonal array (OA) is chosen for design of experiments and the main influencing factor are determined for each given machining criteria by using Analysis of variance (ANOVA). The surface finish have been identified as quality attributes and are assumed to be directly related to productivity. In this experiment we were found that order of significant of main parameter decreasing order is M3>N2>O2>P1.(Tool feed(M), Tool speed(N), Tool diameter(O) and Depth of cut (P)).*

Keywords: *CNC end milling, Surface roughness (SR), Taguchi methodology*

I. INTRODUCTION

Today, industry needs quality and productivity. The increase of consumer needs for quality metal cutting products has driven the metal cutting industry to continuous improve quality control of metal cutting process. The end milling process is one of the most fundamental processes of metal removing process. In order to obtain better surface roughness, the proper setting of cutting parameters is crucial before the process takes place. Several factors will influence the final surface roughness in a CNC milling operation. The final surface roughness might be considered as the sum of two independent effects: 1.The ideal surface roughness is are sult of the geometry of tool and feed rate.2.The natural surface roughness is a result of the irregularities in the cutting operation Factors such as spindle speed, feed rate, tool diameter and depth of cut that control the chip formations, or the material properties of both tool and work piece are Even in the occurrence of chatter or vibrations of the machine tool, defects in the structure of the work material. In end milling, surface finish and material removal rate are two important aspects, which require attention both from industry personnel as well as in Research & Development, because these two factors greatly influence machining performances. In modern industry, one of the trends is to manufacture low cost, high quality products in short time. Automated and flexible manufacturing systems are employed for that purpose. CNC machines are considered most suitable in flexible manufacturing system. Above all,

CNC milling machine is very useful for both its flexibility and versatility. These machines are capable of achieving reasonable accuracy and surface finish. Processing time is also very low as compared to some of the conventional machining process. Which indicates processing time of the work piece, is another important factor that greatly influences production rate and cost? So, there is a need for a tool that should allow the evaluation of the surface roughness before the machining of the part and which, at the same time, can easily be used in the production-floor environment contributing to the minimization of required time and cost and the production of desired surface quality.

II. METHODOLOGY

A. *Analysis of Variance (ANOVA)*:

Analysis of variance (ANOVA) and the F-test (standard analysis) are used to analyse the experimental data [1 ,2 ,3] :

$CF = T^2/n$

$S_T = \sum_{i=1to27} Y_i^2 - CF$

$S_x = (Y_{x1}^2/N_{x1} + Y_{x2}^2/N_{x2} + Y_{z3}^2/N_{x3}) - CF$

f_x = (number of levels of parameter x) – 1

$f_e = f_T - \sum f_x$

f_T = (total number of results) – 1

$V_x = S_x/f_x$

$S_e = S_T - \sum S_x$

$F_x = V_x/V_e$

$V_e = S_e/f_e$

$P_x = S_x'/S_T * 100\%$

$S_x' = S_x - (V_e * f_x)$

$P_e = (1 - \sum P_x) * 100\%$

Where;
CF→ correction factor
n→ total number of experiment
T→ total of all results
S_T → total sum of squares to total variation
Y_i→ value of results of each experiment (i= 1 to 27)
S_x →sum of squares due to parameter x (x= P, Q, R And S)
N_{x1} , N_{x2} , N_{x3} → repeating number of each level (1, 2, 3) of parameter x
Y_{x1} , Y_{x2} , Y_{x3}→ value of results of each level (1, 2, 3) of parameter x
f_x→ degree of freedom (DOF) of parameter x
f_e→ degree of freedom (DOF) of error term
f_T→ total degree of freedom
V_x→ variance of parameter x
S_e→ sum of squares of error term
F_x→ F- ratios of parameter x
V_e→ variance of error term
P_x → percentage contribution of parameter x
S_x'→ pure sum of square
P_e → percentage contribution of error term

B. Design of Experiment or parameter and level setting

We were design experiment to conducting on CNC end milling of three level and four parameter for the optimization of lower surface roughness through the experimental setup by using Taguchi methodology

TABLE I. CONTROL PARAMETER AND THEIR LIMITS

Control Parameter	Level			Observed Values
	1	2	3	
M: Tool feed (mm/min)	1500	2000	2500	Surface Roughness (SR)
N: Tool speed (rpm)	4000	5000	6000	
O: Tool diameter (mm)	10	12	16	
P: Depth of cut (mm)	0.70	0.80	0.90	

TABLE II L9 ORTHOGONAL ARRAY AND OBSERVED VALUES

No. of trial	Control Parameter(Level)				Result/Observed Value Surface Roughness (Ra)		
	M	N	O	P	1	2	3
1	(1500)1	(4000)1	(10)1	(0.70)1	1.34	0.77	1.18
2	(1500)1	(5000)2	(12)2	(0.80)2	0.9	0.84	1.02
3	(1500)1	(6000)3	(16)3	(0.90)3	1.72	1.12	0.78
4	(2000)2	(4000)1	(12)2	(0.90)3	0.66	0.62	0.67
5	(2000)2	(5000)2	(16)3	(0.70)1	0.74	0.78	0.69
6	(2000)2	(6000)3	(10)1	(0.80)2	0.83	2.06	2.35
7	(2500)3	(4000)1	(16)3	(0.80)2	0.71	0.84	0.64
8	(2500)3	(5000)2	(10)1	(0.90)3	0.81	0.82	0.63
9	(2500)3	(6000)3	(12)2	(0.70)1	0.92	0.66	0.72

TABLE II. ANALYSIS OF VARIANCE AND F-TEST FOR SR

Parameter	DOF	S_x	V_x	F-ratio(F_x)	S_x'	P_x
M	2	0.578585	0.289293	2.563641*	0.352896	7.103917
N	2	1.088807	0.544404	4.824373**	0.863119	17.37486
O	2	0.851163	0.425581	3.7714*	0.625474	12.591
P	2	0.417874	0.208937	1.851549*	0.192185	3.86875
e	18	2.0312	0.112844			

***Significant Parameter, * sub significant parameter*

TABLE III. SUMMARIZATION OF SIGNIFICANT PARAMETER ON THE MACHINABLITY OF END MILLING

Parameter	Surface Roughness (SR)
M	*
N	**
O	*
P	*

C. Conformation test

We have found optimal parameter setting for SR as (M3, N2, O2, P1) According to predicted parameter setting with ANOVA calculation. We have conducted the experiments and found SR is **0.69 Ra**. This shows the successful validation of the technique.

III. Experiments

Experimental Setup

The study was carried out using a BFW V-30 CNC vertical milling machine equipped with a maximum Spindle speed 10000 rpm, feed rate 20 m/min, multiple tool-change capabilities (max number of tools = 25) and with 15 HP spindle horsepower The machine is capable of a three-axis movement (along the x, y,and z planes). CNC programs can be developed in the hyper mill software. The work piece material used was AL6351 –T6 in the form of 420mm x 120mm x 20mm plate. The surface roughness measured by Mitutoyo surface roughness tester

IV. RESULTS AND DISCUSSION

Discuses the result for the CNC end milling process parameter we were found main influence control parameter for the minimizing the surface roughness (SR) is that Tool feed (mm/min). Show table V.

TABLE V RESULTS OF THE CONFIRMATION EXPERIMENT FOR SR

Control Parameter	Level	SR (Ra)
M: Tool feed (mm/min)	3	2500
N: Tool speed (rpm)	2	5000
O: Tool diameter (mm)	2	12
P: Depth of cut (mm	1	0.7

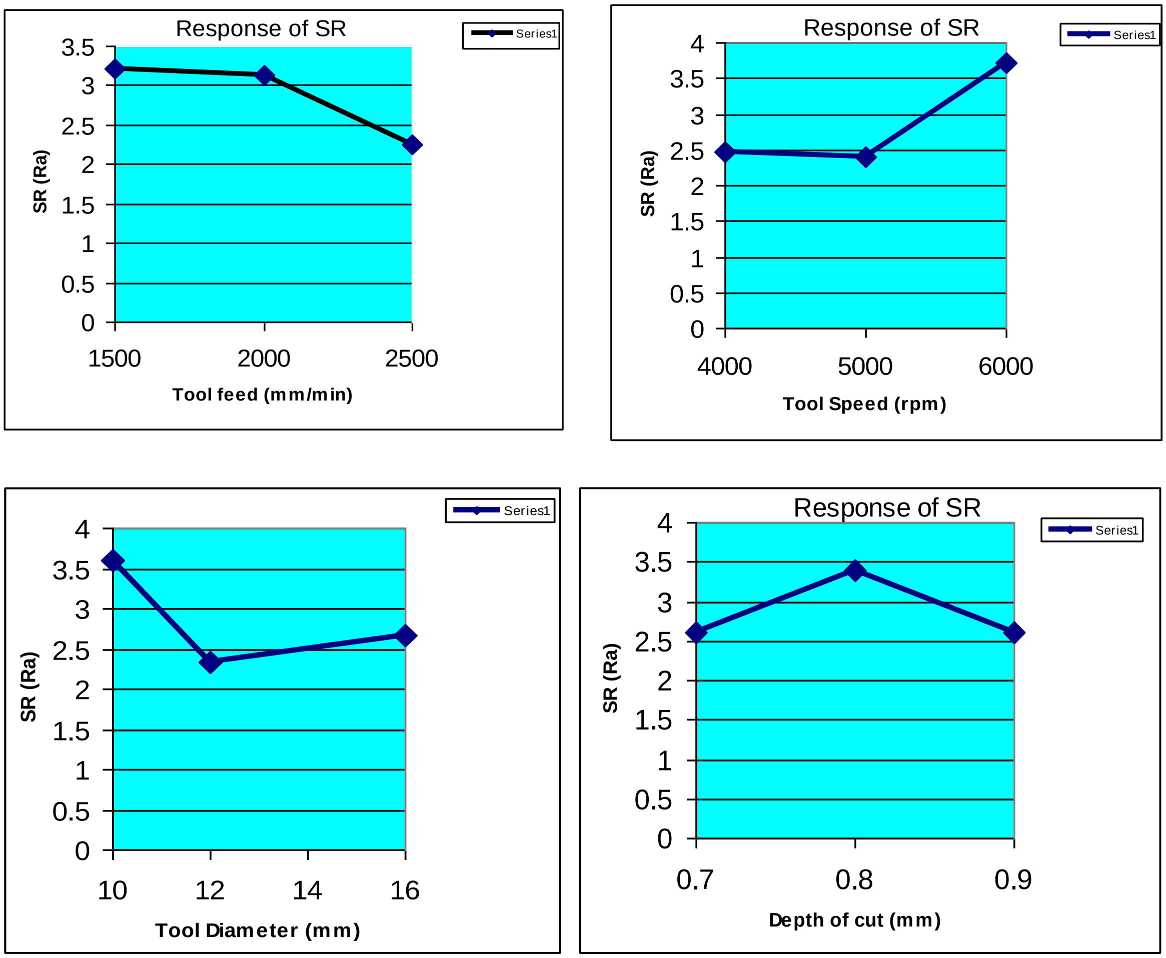

Figure 1: Main effects of each parameter on SR

V. CONCLUSION

In this study the analysis of confirmation experiment and the design of control parameter with there level & four parameters to find the optimal control parameter to minimize the surface roughness that the parameter is ***Tool feed (M)*** as shown in fig.1 and table V, and the order of significance parameter is **M3>N2>O2>P1.**This is the successful validations of the Taguchi methodology

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