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Experimental Investigation of Surface Roughness by Optimizing Process Parameter in Turning Operation of Aluminum Alloy

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***Abstract*— The quality and productivity play very important role in manufacturing technology. The quality such as Surface roughness of any product influences the extent or degree of satisfaction. In this study CNC Lathe was used to perform turning operation and four type coated carbide insert used to use to perform experiment. This study applies Taguchi's design of experiment methodology and regression analysis for optimization of process parameters in turning aluminum alloy AA6063-T6 material using coated carbide insert under dry environment condition and having four type insert nose radius such as 0.2, 0.4, 0.8, 1.2 mm. Experiment have been carried out based on L16 standard orthogonal array design with four process parameters namely cutting speed, feed rate, Depth of cut and nose radius for surface roughness. By considering smaller-the – better approach. Result of ANOVA to indicate that nose radius is the most significant process parameter for surface roughness .The mathematical models have been developed for individual's response using regression analysis.**

Keywords—Machining, Surface Roughness, Orthogonal Array ,Regression Analysis, ANOVA.

I- INTRODUCTION

Turning process is one of the best manufacturing techniques that are used to remove the material from the rotating work piece with the help of stationary single point cutting tool. The primary objective of this process is to obtain the good quality of surface finish. So from the customer's viewpoint this is very important because the quality of products affects the degree of satisfaction of the consumers during usage of the product.

High speed turning operation is done on CNC lathe. The quality of the surface plays a very important role in the performance of dry turning because a good quality turned surface surely improves fatigue strength, corrosion resistance and creep life. Surface roughness also effects on some functional attributes of parts, such as, contact causing surface friction, wearing, light reflection, ability of distributing and also holding a lubricant, load bearing capacity, coating and resisting fatigue. [1]

During the experiments there are many factors which affect the surface roughness. The factors are speed, feed rate, depth of cut, tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. The work piece variables include hardness and mechanical properties of the material.

During the turning operation the selection of process parameter is very difficult to obtain the high surface finish.

In order to achieve these desired performance measures in any machining operation, proper selections of machining parameters is essential. Taguchi Method. Signal to noise (S/N), ratio and orthogonal array are two major tools used in robust design. Signal to noise ratio, which are log functions of desired output measures quality with emphasis on variation, and orthogonal arrays, provide a set of well-balanced experiments to accommodate many design factors simultaneously. The objective of the present work is to obtain the optimum process parameters spindle speed, feed rate, depth of cut and nose radius used in CNC machining on Aluminum AA 6063 T6 work piece to minimize surface roughness and analyze the process parameters which are most significant by using ANOVA. The optimal parametric combination using signal to noise ratio have been found.

Taguchi method is statistical method developed by Professor Genichi for the production of robust products. According to Taguchi, quality of a manufactured product has total loss generated by that product to society from the time has shipped. Taguchi developed a method based on orthogonal array experiments, which reduced "variance" for the experiment with "optimum settings" of control parameters. Thus the combination of Design of Experiments (DOE) with optimization of control parameters to obtain best results.

II-LITERATURE REVIEW

M.Nalbantet et al. [2] have taken orthogonal array, the signal-to-noise ratio, and analysis of variance for study the performance characteristics in turning operation of AISI 1030 steel bars using Tin coated tools. They took three parameter nose radiuses, feed rate and depth of cut for optimized the surface roughness. L9 orthogonal array was used for study. They found that for surface roughness the percentage contributions of insert radius, feed rate and depth of cut are 48.54, 46.95 and 3.39, respectively.

Sing. T. P Singh et al. [3] studied the influence of tool rake angle and nose radius on surface roughness during machining of aluminum material. Authors observed that the surface roughness of the machined surface increase as the nose radius increase. GauravVohra et al. [4] have optimized the boring parameters for aluminum material on CNC turning centre

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such as speed, feed rate and depth of cut, to achieve the highest possible material removal rate the speed and depth of cut are the most significant parameters and for surface roughness speed and feed are the most significant parameters. Vipindas M P et al. [5] worked on finding of an experimental investigation of effects of speed, feed and depth of cut on surface roughness during turning of Al 6061 material using coated carbide inserts. They found that: 1. the lowest surface roughness (Ra) of 0.33microne meter was achieved corresponding to, feed: 0.1mm/rev, Speed: 1000 rpm and depth of cut: 0.4mm and 2. The most significant parameter in influencing the quality of machined surface was feed. N.Prabhakar et al. [6] have studied the influence of machining parameter on surface roughness and material removal rate is examined by using ANN & ANOVA technique. The experiments have been conducted on aaluminium alloy AL 6253 using CNC turner with carbide tip tool and experimental results were analyzed by using ANOVA and the regression equation for predicting the surface roughness and MRR. The ANOVA and ANN results revealed that feed rate and depth of cut are the most significant influencing factors on the material removal rate and surface finish. Rishu Gupta et al. [7] worked on finding of an experimental investigation effect of cutting speed, feed rate, depth of cut and nose radius on material removal rate and surface roughness in CNC turning of Alloy 6061 material. The conclusion revealed that the feed rate and nose radius were the most influential factors on the surface roughness and material removal rate (MRR) in CNC turning process which is greatly influenced by depth of cut followed by cutting speed. S.V. Alagarsamy et al. [8] have conducted experiment by turn aluminum Alloy 7075 using TNMG 115100 tungsten carbide insert at three levels (Speed, feed& DOC) of cutting parameters and analyzed by employing Taguchi method and Response surface methodology were applied for analyzing to get minimum surface roughness and maximum material removal rate for turning process of aluminum Alloy 7075 using CNC machine via considering three influencing to the quality characteristics of surface roughness and depth of cut being most affecting parameter for minimum surface roughness and to analyze the effect of machining parameter and rake angles on the surface finish.

III- EXPERIMENT DETAILS

The experiment was performed with turning of AA6063-T6 material for surface roughness. AA6063-T6 aluminum rod was cut 50 mm length per piece and 25.4 mm diameter used for turning operation. The cutting parameters are shown in table 3. The level of spindle speed, feed rate, nose radius and depth of cut four levels used are shown in table 4.

The L_{16} orthogonal array is selected as per standard suggested Taguchi approach. The base material chemical composition is given in the table 1.

Table1: Material AA 6063-T6 chemical composition.

Mn	Fe	Mg	Si	Cu	Zn	Ti	Cr	others	Al
0.1	0.35	0.45-0.90	0.20-0.60	0.1	0.1	0.1	0.1	0.15	97.5

Fig1: Aluminium AA6063-T6 work piece

Fig2: Tool insert used in turning operation

Fig3: CNC lathe machine

Fig4: AA6063-T6 work piece

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IV- OPTIMIZATION OF SURFACE ROUGHNESS

A- Selection of parameters and levels

The process parameters which are to be optimized were set in levels in the machine range. Each parameter had 4 levels. The effects of these parameters were considered for evaluation effective response. The process parameters with their respective level are shown in table 2.

Table 2: Process parameters and levels

S.No.	Cutting parameters	Level 1	Level 2	Level 3	Level 4
1	Nose radius (mm)	0.2	0.4	0.8	1.2
2	Spindle speed (rpm)	1200	1400	1600	1800
3	Feed rate (mm/rev)	0.04	0.06	0.08	0.10
4	Depth of cut (mm)	0.2	0.25	0.3	0.35

B- Selection of Orthogonal Array

Orthogonal array means the combination of parameters which should be taken while experimenting such that result yields same confidence as if all possible combinations will be taken. For different number of parameters and their levels Taguchi has suggested different orthogonal arrays. Here in this experiment 4 control variable (Nose radius, cutting speed, depth of cut, feed rate) each having 4 levels were taken. Taguchi methodology this experiment will be perfectly done by taking $\mathbf{L_{16}}$ orthogonal array. Taguchi orthogonal array select by using Minitab 17 statistical software.

C- Experiment Procedure

Taguchi analysis is performed according to the selected design of experiment table. The minimum surface roughness developed in each set of combination are noted and tabulated in table. For each experiment the orthogonal array, signal to noise ratio(S/N) are calculated. The quality response is mainly divided into three categories; the smaller is better, larger is better and nominal is better.

Smaller-the-better' S/N = $-10*\log(\sum(Y^2)/n)$ (1)

Larger-the-better' S/N = $-10*\log(\sum(1/Y^2)/n)$ (2)

Nominal-the-better' S/N= $-10*\log(S^2)$ (3)

Where y is the measured data y is the average data s is the variance of y and n is the number of samples. For each type of the characteristic with the above S/N ratio transformation the higher the S/N ratio the better is the result. Minitab 17 statistical software used to calculate S/N ratios for each factor are shown in table 3.

D- Surface Roughness Measurement

There are many method is used to measure surface roughness, such as fingertip, microscopes, stylus type instrument, profile tracing instruments etc. The surface roughness tester SJ- 201P is a shop- floor type surface roughness measuring instrument used in present work. The measured values of the surface roughness are shown in table 3.

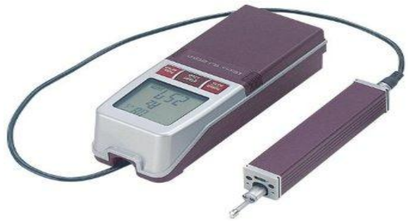

Fig 5: The surface roughness tester SJ-201P

Table 3: Experiment results for surface roughness corresponding S/N ratio of cutting parameters

Run No.	Nose radius (mm)	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Ra (micron meter)	S/N ratio
1	0.2	1200	0.04	0.2	0.5	6.02
2	0.2	1400	0.06	0.25	0.52	5.67
3	0.2	1600	0.08	0.3	0.69	3.22
4	0.2	1800	0.1	0.35	0.71	2.97
5	0.4	1200	0.06	0.3	0.48	6.74
6	0.4	1400	0.04	0.35	0.38	8.40
7	0.4	1600	0.1	0.2	0.60	4.43
8	0.4	1800	0.08	0.25	0.52	5.67
9	0.8	1200	0.08	0.35	0.37	8.63
10	0.8	1400	0.1	0.3	0.38	8.87
11	0.8	1600	0.04	0.25	0.40	7.95
12	0.8	1800	0.06	0.2	0.46	6.74
13	1.2	1200	0.1	0.25	0.32	9.89
14	1.2	1400	0.08	0.2	0.35	9.11
15	1.2	1600	0.06	0.35	0.34	9.37
16	1.2	1800	0.04	0.3	0.36	8.63

Table 4: Response table for signal to noise ratio smaller is better (Ra)

Level	Nose radius (mm)	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)
1	4.475	7.732	7.814	6.580
2	6.224	7.902	7.043	7.304
3	7.936	6.247	6.664	6.719
4	9.315	6.068	6.428	7.346
Delta	4.840	1.833	1.386	0.766
Rank	1	2	3	4

From the table 4 delta values it assigns the rank to each which is having more influence on the mean of surface roughness. From the results S/N ratio also it is observed that nose radius is the dominant factor for surface roughness.

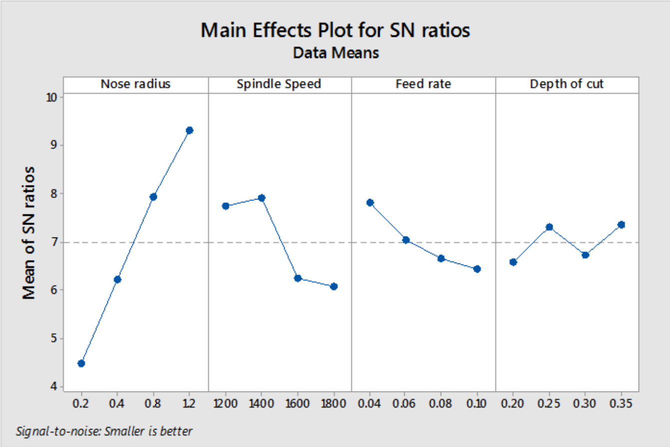

Fig 6: Graphical results for surface roughness (Ra)

From the above graph, the optimum values for the surface roughness are (a): nose radius 1.2 mm (b): Spindle speed 1400 rpm (c): Feed rate 0.04 mm/rev (d): Depth of cut 0.35 mm.

The grater S/N ratio values are considered for the smaller-the-better criteria. Higher S/N ratio value gives the better result for both minimizing and maximizing response so always higher S/N ratio value are taken.

Table 5: Analysis of variance (ANOVA) for surface roughness (Ra)

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contribution
Nose radius	3	52.857	52.857	17.6191	43.58	0.006	73.94%
Spindle speed	3	11.133	11.133	3.7109	9.18	0.051	15.57%
Feed rate	3	4.416	4.416	1.4719	3.64	0.158	6.17%
Depth of cut	3	1.867	1.867	0.6224	1.54	0.366	2.61%
Error	3	1.213	1.213	0.4042			
Total	15	71.486					

S = 0.6358, R-Sq = 98.3 %, R-Sq (adj) = 91.5 %

Minitab 17 statistical software used to obtain ANOVA table for surface roughness. In ANOVA table P value is set in terms of (Alpha = 0.05). If P value is below 0.05 then parameters are significant level and ANOVA also define as contribution factor for each parameter.

It is clear shows that table 5 Nose radius is most significant parameter for surface roughness.

V- REGRESSION ANALYSIS (RA)

It is used to investigate and model the relationship between a response variable and one or more predictors. The dependant variable surface roughness (Ra) can be conceived as a linear combination of the independent variable, namely as nose radius, spindle speed, feed rate and depth of cut. The data was analyzed by Minitab 17 statistical software. Multi regression analysis was conducted on the tested data. Developed model can be used to predict value for surface roughness (Ra).

Surface roughness (Ra) = 0.251-0.2496(Nose radius) + 0.000192 (Spindle speed) + 1.550 (Feed rate) – 0.090 (DOC) (4)

Table 6: Coefficient of analysis

Term	Coef	SE Coef	T- value	P- value	VIF
Constant	0.251	0.116	2.17	0.053	
Nose radius	-0.2496	0.0331	-7.53	0.000	1.00
Spindle speed	0.000192	0.000057	3.38	0.006	1.00
Feed rate	1.550	0.569	2.72	0.020	1.00
Depth of cut	-0.090	0.228	-0.40	0.700	1.00

S = 0.0509051, R-Sq = 87.32%, R-sq (adj) = 82.71%, Rsq (pred) = 75.61%

Table 7: Analysis of variance

Source	DF	Adj SS	Adj MS	F- value	P- value
Regression	4	0.196270	0.049068	18.94	0.000
Nose radius	1	0.147000	0.147000	56.73	0.000
Spindle speed	1	0.029645	0.029645	11.44	0.006
Feed rate	1	0.019220	0.019220	7.42	0.020
Depth of cut	1	0.000405	0.000405	0.16	0.700
Error	11	0.28505	0.002591		
Total	15	0.224775			

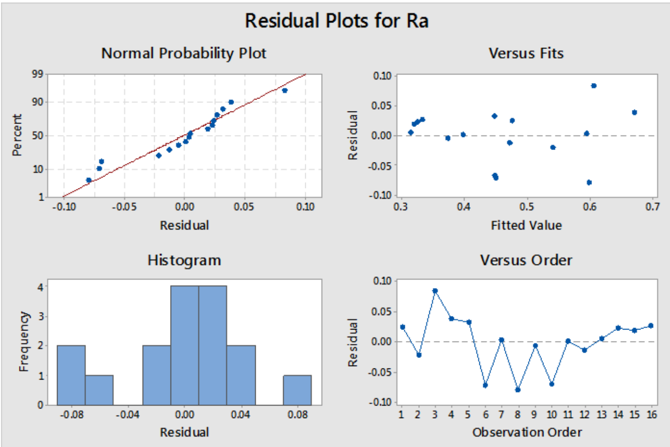

Fig 7: Residual plots for surface roughness

CONFIRMATORY TEST RESULTS:

Once the optimal level of the process parameter used in regression equation (4) find out prediction value of the surface roughness. Again optimal process parameter taken to done turning operation and find out experiment value of the surface roughness given table 8.

Table 8: Prediction value and Experiment value of the surface roughness (Ra)

Nose radius (mm)	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Predicted value of Ra	Experi ment value
1.2	1400	0.04	0.35	0.2508	0.3014

From the above table shows that prediction value and experiment value of surface roughness are very close together and lower error validated the experiment.

CONCLUSION:

Experiments were done to optimize cutting parameters during turning of aluminium alloy AA6063-T6 using tungsten carbide insert. The cutting parameters are nose radius, spindle speed, feed rate, and depth of cut. The following conclusion drawn from the present investigation-

1-Based on the S/N analysis, the optimal process parameter for surface roughness are as follows: Nose radius level 4, spindle speed level 2 feed rate levels 1, and DOC at level 4, N4-S2-F1-D4.

2-In single optimization technique for Ra the prediction result value 0.2508 µm and experiment result value 0.3014 µm.

3-It is evident that the Nose radius is the most significant parameter for surface roughness in ANOVA study.

4-The highest S/N ratio in predicted result indicates that the optimization model is adequate.

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