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Experimental Investigation of Machining Parameters for Aluminum 6061-T6 Alloy

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ABSTRACT

In the present work, Turning Parameters were optimized using Taguchi Method. Also, the effect of turning parameters such as rotational speed, feed rate, depth of cut and material removal rate on surface roughness of Aluminum 6061-T6 alloy was investigated. L9 Taguchi's method was used for designing the experiments and optimization of turning parameters. Nine experiments were conducted with four factors having three levels for each factor. Results revealed that spindle speed has a significant effect on surface roughness and it is the most dominating factor affecting the surface roughness with contribution of 52.38%. The optimal parameter combination of Aluminum 6061-T6 alloy bar for minimum surface roughness is found to be A2 B1 C2 D i.e., rotational spindle speed (A) at 900 rpm, feed rate (B) at 90 mm/min and depth of cut (C) at 0.8 mm, and material removal rate (D).

KEYWORDS: *L9- Taguchi Method; Surface Roughness; Aluminum 6061-T6 alloy; Robust design Method; Turning*

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I. INTRODUCTION

In the process of machining, raw materials are transformed into desirable components with the required precision and size. Metal cutting is a highly nonlinear and linked thermo-mechanical process, where mechanical work is turned into heat through plastic deformation involved during chip creation as well as due to frictional work between the tool, chip, and work piece.

Robust design Method

The Robust design Method is also known as Taguchi method. The Taguchi method, a statistical technique created by Taguchi and Konishi, was first designed to enhance the quality of manufactured items (developing manufacturing processes), but later its applications were broadened to numerous other engineering disciplines, such as biotechnology. Professional statisticians have praised Taguchi's achievements, particularly those related to the creation of designs for analysing variation. In order to successfully achieve the intended results, process parameters must be carefully chosen and divided into control and noise elements. It is necessary to choose the control elements in a way that cancels out the impact of noise sources. To achieve the best results from the process, the Taguchi Method entails the identification of suitable control parameters. To investigate how different process variables affect the machining process, analysis of variance (ANOVA) is employed.. The method is based on the Taguchi method, and in order to analyse the performance characteristics, the signal to noise (S/N) ratio and analysis of variance (ANOVA) are used.

Turning

Turning is a very simple procedure that typically results in cylindrical surfaces. A lathe is the name of the machine tool used for this kind of activity. One of the most often used operations in experimental work and metal cutting is turning.

Cutting Factors in Turning are as:-
spindle speed: Speed always refers to the spindle and the work piece. In turning V in m/s is related to the rotational speed of the workpiece by the equation:

$V = \pi DN$

Where V is the cutting speed in m/s
D is the diameter of the work piece, m;
N is the rotational speed of the work piece, rev/s.

Feed: Feed is defined as the distance that a advance into the work during one revolution of the headstock spindle. It is usually given as a linear movement per revolution of the spindle or job. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev. F= f*N mm/min

Here, F is the feed in mm per minute, f is the feed in mm/revand N is the spindle speed in RPM

Depth of Cut
Depth of cut is practically self-explanatory. It is the thicknessof the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm.

Tool nose radius: tool nose radius effects the strength of tool as well as it effects the surface roughness of the work piece very much

II. OBJECTIVE OF THE STUDY

The objective of this study is to illustrate the procedure adopted in using Taguchi Method to a lathe facing operation.The orthogonal array, signal-to-noise ratio, and the analysis of variance are employed to study the performance characteristics on facing operation. In this analysis, four factors namely speed, feed and depth of cut and material removal rate were considered. Accordingly, a suitable orthogonal array was selected and experiments were conducted. After conducting the experiments the surface roughness was measured and Signal to Noise ratio was calculated. With the help of graphs, optimum parameter values were obtained andthe confirmation experiments were carried out. These results were compared with each other to find the optimum combination of the machining parameters for surface roughness.

III. LITERATURE REVIEW

Rajesh Mahto et al. [1].discussed the process parameter of heat treatment of low carbon steel by using Taguchi approach and Fuggy Logic approach. In bearing industry, when shell of bearing is heat treated then shell has not optimum hardness due to unsuitable process parameter such as carburizing temperature, carbon potential, holding time and quenching time. So, his aim is to obtain optimizing condition of different parameter in order to get sufficient hardness of low carbon steel as per requirement. Taguchi and Fuggy logic approach both are optimizing software.

P. G. Inamdar et al. [2]. optimise the surface roughness in conventional turning operation using Taguchi Method for the material medium carbon steel EN8. In this work cutting speed, feed rate and depth of cut are taken as performance parameters to achieve better surface roughness. Taguchi Method is used to obtained the main parametric effect on the surface roughness using their levels and factors. L9 orthogonal array is used to design the experiments. Also analysis of variance (ANOVA) was carried out with the significance factor of 95%. After the experimentation, it was found that cutting speed has more influenced on the surface roughness in conventional turning process than feed rate and depth of cut.

Abburi et al. [3]. developed a knowledge-based system for the prediction of surface roughness in turning process. Fuzzy set theory and neural networks were utilized for this purpose. The authors developed rule for predicting the surface roughness for given process variables as well as for the prediction of process variables for a given surface roughness. Ali. et al. [4]. recognized the importance of achieving dimensional accuracy, good surface finish and maximum material removal rate in the machining process; and optimized the cutting parameters viz. Feed, cutting speed anddepth of cut for maximizing the surface finish and material removal rate for an aluminium alloy 6061. L-8 orthogonal array, signal-to-noise ratio, analysis of variation has been employed to study the process characteristics, and L8 Taguchi method experiment design has been used to optimizethe cutting parameters for the material using uncoated inserts.An experiment has been conducted to confirm and verify the effectiveness of Taguchi optimization method. Surface roughness and material removal rate are found to be maximum at 11.6%and 14%; and minimum at 4.4% and 3.7% respectively. Cutting parameters viz. cutting speed, feed rate and depth of cut are found to be affecting the machining process at 45%, 36% and 19% respectively for minimum surface finish of 0.256 microns with an error percentage of 4.4%

Abhang et al. [5]. carried out the experimental work to optimize the cutting parameters viz. feed rate, depth of cut and lubricant temperature in the turning operation of EN-31 steel alloy by using tungsten carbide inserts. The work aimed at explaining and demonstrating the systematic procedure of Taguchi parameter design; finding the optimal combination of cutting parameters using the signal-to-noise ratio; knowing the significance level of each cutting parameter using ANOVA analysis; and therefore, finding out the effect oflubricating temperature on the response i.e. surface finish. It has been proved experimentally that better surface finish can be observed with cooled lubricant and higher depth of cuts Al-Ahmari [6]. developed empirical models for tool life, surface roughness and cutting force for turning operation. The process parameters used in the study were speed, feed, depth of cut and nose radius to develop the machinability model. The methods used for developing aforesaid models were Response Surface Methodology (RSM) and neural networks (NN).

Ilhan et al. [7]. focused on optimizing turning parameters based on Taguchi method to minimize surface roughness (Ra and Rz). Experiments have been conducted using L8 orthogonal array in a CNC turning machine. Dry turning tests were carried out on hardened AISI 4140 (51 HRC) with coated carbide cutting tools. As a result, they observed that the feed rate has the most significant effect on Ra and Rz.

Ahmed [8]. developed the methodology required for obtaining optimal process parameters for prediction of surface roughness in Al turning. For development ofempirical model nonlinear regression analysis with logarithmic data transformation was applied. The developed model showed small errors and satisfactory results. The study concluded that low feed rate was good to produce reduced surface roughness and also the high speed could produce high surface quality within the experimental domain.

Choudhary et al. [9]. discussed the development of surface roughness prediction models for turning EN 24T steel (290 BHN) utilizing response surface methodology. A L8- OA factorial design technique was used to study the effects of the main cutting parameters such as spindle speed, feed and depth of cut, nose radius on surface roughness.

MATERIAL USED

For the experiments, we have taken the Aluminum alloy. This Aluminum 6061-T6 alloy contain 95.8 to 98.6 % of aluminum, chromium which range is from 0.04 to 0.35% and copper 0.15, Iron 0.7. First of all we considered the microstructure of cooled Aluminum alloy which contain small amount of Manganese 0.15%, Silica 0.4%, zinc 0.25%.

Table 1 physical properties

Property	Standard	Metric
Density at room temperature	0.0975 lb/in.^{3}	2.70 x 10^3 kg/m^3
Shear modulus at room temperature	3770 ksi	2 6 (GPa)
Melting point	1080-1205 °F	582-652°C
Poisson's Ratio at room temperature	0.33	0.33

Table 2 Mechanical properties

Properties	Metric	Imperial
Tensile strength, ultimate	310 MPa	45000 psi
Tensile strength, yield	276 MPa	40000 psi
Modulus of elasticity	68.9 GPa	10000 ksi

IV. EXPERIMENTAL PROCEDURE

- From an Aluminum alloy bar, nine bars were cut bypower hacksaw
- Turning operation is started after setting the workmaterial
- Turning is done on nine individual bars as per L_9-OA
- After machining on lathe machine, we measured surface roughness of each bar by surface roughnesstester
- Two readings (repetition) on each bar was taken byhelp of surface roughness tester.
- Taguchi experimental design is done and we find the optimal combination of factors and their levels.

Experimental Design

L_9-Taguchi method, a powerful tool for parameter design of performance characteristics, was used to determine optimal machining parameters for minimum surface roughness in turning process. The optimal level of the process parameters is the level with the higher S/N ratio. The lower the better criterion for the surface roughness was selected for obtaining optimum machining performance characteristics.

For lower the better criteria, S/N ratio values correspondingto the experimental values of surface roughness was calculated using the below equation.

$$\frac{S}{N} = -10 \log (y^2)$$

Nine experimental runs based on the orthogonal array L9 were carried out.

Design of Experiments (DOE)

The DOE help for conducting experiments in a more systematic way. The process parameters with their levels are specified in Table no. 3 below.

Table No. 3

Factor	symbol	Level-1	Level-2	Level-3
Spindle speed (rpm)	A	800	900	1000
Feed rate (mm/min)	B	90	135	180
Depth of cut(mm)	C	0.5	0.8	1

Orthogonal Array (OA)

OA allows for the maximum number of main effects to be estimated in an orthogonal manner, with minimum number of runs in experiment, L_9 orthogonal array usedas shown in Table 4.

Table 4 Orthogonal array L_9

ti	(A) Spindle Speed (Rpm)	(B) Feed Rate (mm/min)	(C) Depth of Cut (mm)	Level
1	800	90	0.5	1-1-1
2	800	135	0.8	1-2-2
3	800	180	1	1-3-3
4	900	90	0.8	2-1-2
5	900	135	1	2-2-3
6	900	180	0.5	2-3-1
7	1000	90	1	3-1-3
8	1000	135	0.5	3-2-1
9	1000	180	0.8	3-3-2

V. RESULTS AND DISCUSSIONS

Nine experiments were successfully conducted based onTaguchi L_9 method and machined samples are shown in Fig.

1. The experimental results for the surface roughness alongwith corresponding S/N ratios are listed in Table No.5.

Fig 1. Machined work piece

Table 5 Experimental Results and S/N ratio

Job No.	Level	(D) MRR	Roughness (R)	(S/N) (Smaller the best)
1	1-1-1	598.67	1.874	5.45539
2	1-2-2	784.57	1.61	4.13652
3	1-3-3	2924.58	1.853	5.35751
4	**2-1-2**	**900.71**	**1.479**	**3.39936**
5	2-2-3	5623.74	2.512	8.00039
6	2-3-1	1307.42	2.755	8.80243
7	3-1-3	6904.38	2.502	7.96575
8	3-2-1	3149.93	2.822	9.01114
9	3-3-2	7255.03	2.973	9.35808

Analysis of Mean (ANOM) In ANOM, mean value of the S/N ratio at each level of the process parameters is computedby taking arithmetic mean average of S/N ratio at the selected level.

Best combination so generated is $A_2 B_1 C_2 D$

VI. CONCLUSION

This work presents an experimental study in which turning operation is performed on Aluminum 6061-T6 alloy using carbide tool. The effect of four machining parameters namely speed, feed rate, depth of cut and material removal rate on the surface roughness was investigated. Experimentation was done as perTaguchi's L9 orthogonal array. Response variable (surface roughness) was measured, signal to noise ratio values were computed, subsequently, and by investigation it was found that $A_2 B_1 C_2 D$ as best combination.

The analysis of mean is performed to obtain optimum levelof machining parameters for surface roughness.

Following conclusion is drawn from the present study:

- Taguchi's robust design was successfully used for optimizing turning parameters on Aluminum 6061-T6 alloy.
- Optimal combination of the machining parameters for surface roughness is found to be $A_2 B_1 C_2 D$, i.e., at spindle speed (A) at 900 rpm, feed rate (B) at 90 mm/min and depth of cut (C) at 0.8 mm, and material removal rate (D).
- Tool Spindle speed contributes maximum (52.38%) followed by depth of cut (31.97 %) and feed rate (15.64%) to minimize the surface roughness.

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