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# EVALUATION OF SURFACE ROUGHNESS IN ALUMINIUM ALLOY USING DIFFERENT CUTTING CONDITIONS

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## ABSTRACT

Quality and productivity play important role in manufacturing technology. The quality of any product influences the extent or degree of satisfaction of the consumers during its usage & so quality becomes a major concern for every manufacturing unit. Today's manufacturing industry needs to produce products within lesser time with no compromise shown on quality; in order to tackle these two contrasting criteria; it is necessary to check the quality level of the product either offline or online. In a manufacturing unit, one of customers most specified requirement is surface roughness which is an indicator of the surface quality. In this present work an offline estimation of surface roughness and its variation with respect to changing cutting parameters in turning of aluminium alloy is carried out. Taguchi DOE and ANOVA are employed for finding out the most suitable cutting parameters for minimizing surface roughness. The percentage contribution of each factor towards decreasing the roughness in aluminium alloy is found out

**Keywords**: design of experiments, ANOVA, MINITAB

## NOMENCLATURE

Y-vertical deviation from nominal surface
Ra-surface roughness
Lm-specified length on surface.
S/N-Signal to Noise ratio.

## 1. INTRODUCTION

Surface roughness and surface finish are opposite to each other, these are quantitative parameters. Surface roughness can be expressed in units of length after its measurement. "Measurement of finely spaced deviations of actual surface from nominal surface (datum) in the units of length (µm) is the measurement of surface roughness. Lesser the value of surface roughness better the surface finish is said. There are two popular methods of expressing measured value of surface roughness.

According to “AA” method surface roughness is the average of vertical deviations from the nominal surface over a specified surface length.

$$\text{Average roughness (AA)} = \int_0^{lm} \frac{(Y)}{Lm} dx \qquad (1)$$

According to root mean square method, “Value of surface roughness is square root of the mean of the squared deviations from nominal surface over the measuring length (sampling length)” RMS value is always observed more than the arithmetic average because larger deviations play more prominent role.

$$\text{Ra rms} = \int_0^{lm} \sqrt{\frac{Y^2}{Lm}} dx \qquad (2)$$

Surface roughness is one of the most important requirements in machining process, as it is considered as index of product quality. It measures the finer irregularities of the surface texture. Desired value of surface roughness of a product is generally defined to achieve the required fatigue strength, corrosion resistance, precision fits, tribological and aesthetic requirements. The ability of a manufacturing operation to produce a desired surface roughness depends on various parameters like machining parameters, tool and work piece material properties and cutting conditions. In turning operation the surface roughness depends on cutting speed, feed rate, depth of cut, tool nose radius, lubrication of cutting tool , machine vibrations etc. even small change in any of the mentioned factors may have a significant effect on produced surface [1]. Optimization of turning operations was carried out in EN-31 steel alloy using a carbide tool insert by l.b abhang, et al. [2]; 9 experiments were performed; the important aim of the paper studied was to analyze the effect of lubricant temperature, depth of cut & feed rate on surface roughness which was not being studied earlier; ANOVA analysis was performed to find the significant parameter affecting Ra. Among the 3 design parameters lubricant temperature contributed more on minimizing surface roughness (73.5%) followed by feed rate and depth of cut. Multi response optimization of turning operation was carried out in AISI 304 austenitic stainless steel by Iihan asilturk, et al. [3] .The influence of cutting speed, feed, and depth of cut on surface roughness was examined. Finally the model for surface roughness as a function of cutting parameters is obtained using the response surface methodology. The study revealed that feed rate is the most significant factor contributing surface roughness with a percentage contribution of 85%. Multi response optimization of surface roughness and tool wear in Al/SiC particulate MMC using taguchi grey relational analysis by S.tamang, et al. [4] extended the concept of analyzing multiple effects (Ra & tool wear rate) , this method does not required any mathematical computation. The objective of gray relational analysis is to convert the multi response problem into a single objective problem. The influence of surface roughness, material removal rate and power consumption on EN353 was studied using two tools PVD & CVD coated tool by Sharma, et al. [5] . The objective of the study was to minimize the surface roughness and power consumption and maximize MRR. But the study revealed no coincidence between operating conditions which will minimize power consumption, surface roughness and maximize MRR. The present work emphasis on the experimentation of prediction of surface roughness in aluminium alloy to optimize machining parameters namely speeds, feed rate, depth of cut. 27 experimental runs are conducted based on taguchi design of experiments on aluminium alloy using carbide tipped tool and ANOVA analysis is performed on MINITAB 16 software.

## 2. DESIGN OF EXPERIMENTATION

Experimental design techniques are a powerful approach in product and process development, and they have an extensive application in engineering areas. Potential applications include product design optimization, process design optimization, material selection and many others. Dr. Taguchi developed a method to optimize the process of engineering experimentation which is now known as Taguchi methods. Taguchi method is a powerful tool for the design of high quality systems. It provides an efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method explores the concept of quadratic quality loss function and uses a statistical measure of performance called signal to noise (S/N) ratio. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. The standard S/N ratios generally used are as follows:

1. Taguchi S/N ratio for nominal the best:

E.g.: diameter

$$S/N=10\ log10\ \frac{1}{n}\sum_{i=1}^{n}\frac{\mu^2}{\sigma^2} \qquad (3)$$

2. Taguchi S/N ratio for smaller the best:

E.g.: defects

$$S/N = -10\ \log_{10}\frac{1}{n}\sum_{i=1}^{n}y_i^2 \qquad (4)$$

3. Taguchi S/N ratio for higher the better:

E.g.: current

$$S/N = -10\ \log_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2} \qquad (5)$$

In the current scenario, our area of interest is to minimize the surface roughness and hence we adopt taguchi S/N ratio for smaller the better.

The factors and their various levels were selected based on the literature survey and from design data book. Table 1 shows the various control factors that are considered for the experiments and their levels, $L_{27}$ orthogonal array was used for the experimentation. 27 combinations of input parameters were used to study the effect of surface roughness.

TABLE 1: Control factors and levels

| **Control factors** | **Level 1** | **Level 2** | **Level 3** |
|---|---|---|---|
| **Feed rate(mm/rev)** | 0.1 | 0.2 | 0.4 |
| **Depth of cut(mm)** | 0.3 | 0.6 | 1 |
| **speed (rpm)** | 400 | 500 | 600 |

## 3.EXPERIMENTATION

The experiment was conducted to analyze the effect of design parameters such as feed rate, speed and depth of cut on surface roughness. The 3 design parameters were studied at three levels, a 3 factor, 3 level ($3^3$) experimental runs were carried out on aluminum alloy using carbide tipped tool. The design of experiments is implemented based on Taguchi method of selection of orthogonal array L27. The experiment was carried out in dry condition on two-axis CNC lathe machine (GEDEE WEILER) which has a maximum spindle speed of 4500 rpm. The machined Aluminium alloys were examined in surface roughness tester to determine the average surface roughness. The experimental conditions are shown on

TABLE 2: Experimental Conditions

| | |
|---|---|
| Machine tool | GEEDEE WEILER CNC LATHE |
| Work material | Aluminiumalloy,500mm length,35 mm diameter |
| Tool material | Carbide tipped tool |
| Nose radius | 1.2 mm |
| Work material composition | Aluminium+ Si (0.8%) +Zn (0.1%) +Fe (0.5%) +Cu (0.1%) +Mn (0.03%) + Mg (0.6%) +Cr (0.03%) +B (0.06%) |

FIGURE 1: Step turned Al bars.

Figure 1 shows the aluminium bars which are step turned using carbide tipped tool, 9 sets of work pieces were machined and 27 experimental runs were performed.


Figure 2 shows surface roughness tester. The surface roughness is measured in surface roughness tester surfcoder.

## 4. **RESULTS & DISCUSSIONS**

Table 3 shows the surface roughness values obtained after experimentation; the surface roughness was measured in surface roughness tester (surfcoder). The table also shows S/N ratios; Taguchi uses the S/N ratio to measure the quality characteristics deviating from the desired value. From the three categories of quality characteristics lower the better is used for surface roughness for obtaining optimal cutting performance.

Since the experimental design is orthogonal, it is then possible to separate out the effect of each cutting parameter at different levels. For example the mean S/N ratio for feed rate at level 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiment (1-3, 4-6, 7-9 etc). The mean S/N ratio for each level of other cutting parameters can be computed in similar manner.

The analysis was performed using MINITAB 16 software, the signal to noise ratio and means were calculated by considering lower the better value for the response surface roughness. The relative importance amongst the cutting parameter levels is determined more accurately in ANOVA analysis. The S/N response table for surface roughness is shown in table 4.

TABLE 3: Experimental results for surface roughness and S/N ratio

| **Exp.No** | **Speed (rpm)** | **Feed(mm/rev)** | **Depth of cut(mm)** | **Surface roughness (Ra)** µm | **S/N ratio** |
|---|---|---|---|---|---|
| **1.** | **400** | **0.4** | **0.3** | **2.050** | **-6.23508** |
| **2.** | **400** | **0.4** | **0.6** | **3.900** | **-11.8213** |
| **3.** | **400** | **0.4** | **1.0** | **2.760** | **-8.81818** |
| **4.** | **400** | **0.2** | **0.3** | **1.640** | **-4.29688** |
| **5.** | **400** | **0.2** | **0.6** | **1.700** | **-4.60898** |
| **6.** | **400** | **0.2** | **1.0** | **1.920** | **-5.66602** |
| **7.** | **400** | **0.1** | **0.3** | **1.690** | **-4.55773** |
| **8.** | **400** | **0.1** | **0.6** | **1.880** | **-5.48316** |
| **9.** | **400** | **0.1** | **1.0** | **2.250** | **-7.04365** |
| **10.** | **500** | **0.4** | **0.3** | **2.980** | **-9.48433** |
| **11.** | **500** | **0.4** | **0.6** | **3.240** | **-10.2109** |
| **12.** | **500** | **0.4** | **1.0** | **3.770** | **-11.5268** |
| **13.** | **500** | **0.2** | **0.3** | **1.282** | **-2.15776** |
| **14.** | **500** | **0.2** | **0.6** | **0.849** | **1.421846** |
| | | | | | |
| **15.** | **500** | **0.2** | **1.0** | **1.663** | **-4.41784** |
| **16.** | **500** | **0.1** | **0.3** | **1.840** | **-5.29636** |
| **17.** | **500** | **0.1** | **0.6** | **1.980** | **-5.9333** |
| **18.** | **500** | **0.1** | **1.0** | **2.140** | **-6.60828** |
| **19.** | **600** | **0.4** | **0.3** | **2.340** | **-7.38432** |
| **20.** | **600** | **0.4** | **0.6** | **2.130** | **-6.56759** |

| | | | | | |
|---|---|---|---|---|---|
| **21.** | **600** | **0.4** | **1.0** | **3.198** | **-10.0976** |
| **22.** | **600** | **0.2** | **0.3** | **1.870** | **-5.43683** |
| **23.** | **600** | **0.2** | **0.6** | **1.890** | **-5.52924** |
| **24.** | **600** | **0.2** | **1.0** | **1.705** | **-4.63449** |
| **25.** | **600** | **0.1** | **0.3** | **1.670** | **-4.45433** |
| **26.** | **600** | **0.1** | **0.6** | **2.040** | **-6.1926** |
| **27.** | **600** | **0.1** | **1.0** | **1.850** | **-5.34343** |

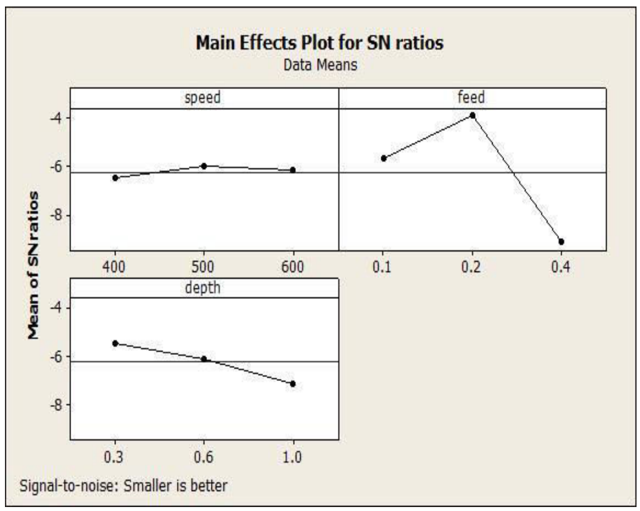


FIGURE 3: S/N graph for surface roughness

Figure 4 depicts a 3D surface plot of surface roughness (µm) v/s feed rate and depth of cut which shows the minimum value of surface roughness or better surface finish is obtained at a minimum depth of cut of 0.3 mm and at a medium feed rate of 0.2 mm/rev.

TABLE 4: response for surface roughness

| **Level** | **Speed** | **Feed rate** | **Depth of cut** |
|---|---|---|---|
| **1** | -6.503 | -5.657 | -5.478 |
| **2** | -6.024 | -3.925 | -6.103 |
| **3** | -6.182 | -9.127 | -7.128 |
| **Delta** | 0.480 | 5.202 | 1.650 |
| **Rank** | 3 | 1 | 2 |

The delta in table 4 is the difference between the maximum and minimum values; it shows that feed rate is the most influential parameter. From the figure 3 it is clearly observed that improved surface finish in aluminium bar is obtained at medium spindle speed (500 rpm), feed rate at medium level (0.2 mm/rev) and at minimum depth of cut (0.3mm).

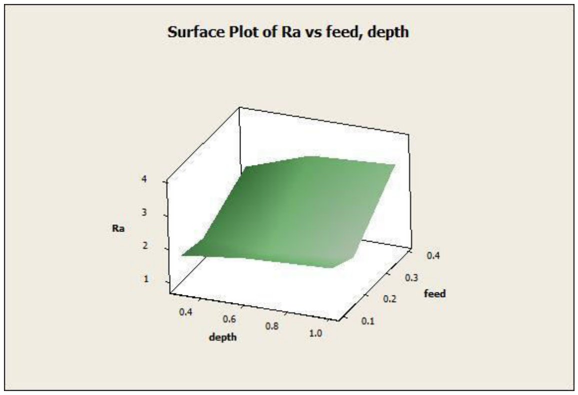


FIGURE 4: 3D surface plot of surface roughness(µm) with feed rate and depth of cut

ANOVA analysis is done in order to find out the significance of each parameter influencing surface roughness, the interactions between various factors of an experiment can be quantitatively determined by using the analysis of variance (ANOVA). Table 5 summarizes the ANOVA analysis performed using MINITAB 16 software. The results shows that feed rate is the most important parameter that influences surface roughness with a percentage contribution (PC) of 63.71% followed by the interaction of speed and feed rate with 10.5% .

| SOURCE | DF | Seq SS | Adj MS | F | P | P.C |
|---|---|---|---|---|---|---|
| V | 2 | 0.0999 | 0.0500 | 0.27 | 0.772 | 0.75 |
| F | 2 | 8.4461 | 4.2230 | 22.59 | 0.001 | 63.71 |
| Doc | 2 | 0.7825 | 0.3913 | 2.09 | 0.186 | 5.90 |
| v*f | 4 | 1.3920 | 0.3480 | 1.86 | 0.211 | 10.50 |
| f*doc | 4 | 0.5154 | 0.1289 | 0.69 | 0.619 | 3.88 |
| v*doc | 4 | 0.5249 | 0.1312 | 0.70 | 0.612 | 3.95 |
| Error | 8 | 1.4953 | 0.1869 | | | 11.28 |
| Total | 26 | 13.2562 | | | | 100 |

Table 5: analysis of varience of surface roughness

## 5. CONCLUSION

1. ANOVA analysis is done in order to find out the significance of each parameter influencing surface roughness.
2. The interactions between various factors of an experiment can be quantitatively determined using ANOVA analysis.

3. The improved surface finish in aluminium bar is obtained at medium spindle speed (500 rpm), feed rate at medium level (0.2 mm/rev) and at minimum depth of cut (0.3mm) for the specific test range.
4. The results shows that feed rate is the most important parameter that influences surface roughness with a percentage contribution (PC) of 63.71% followed by the interaction of speed and feed rate with 10.5% .

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