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OPTIMIZATION OF PROCESS PARAMETERS ON ALUMINIUM ALLOY ADC12 MATERIAL USING TAGUCHI IN CNC TURNING

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Abstract: The life time of any work piece depends up on its surface properties. Because it is in direct contact with atmosphere. In today's manufacturing industries quality is one of the significant factors, the only component to influence the customer to a level of satisfaction. In every industrial sector surface quality is detected by the surface roughness of the component. The demand for high quality aluminium alloys with good surface finish increasing day by day because of newer applications in various fields like aerospace, automobile, die and mould manufacturing and thus manufacturers are required to increase productivity by improving surface quality by avoiding stress concentrators on the surfaces. Some of the parameters which effect the work piece at the time of machining are namely cutting speed, depth of cut, feed and nose radius, cutting environment(dry or wet), etc.

The experiment will be carried on three machining parameters, viz., speed, feed and depth of cut as independent variables and the surface roughness parameter as response variable. The experimentation plan is designed by using design of experiment (DOE).This experiment is machined on CNC Turning Machine and the process will be carried on the AL-ALLOY ADC12 Material the measurement of surface roughness will be carried out by using stylus-profilometer.

The optimum cutting condition was determined by using the TAGUCHI is one of the optimization techniques for optimizing the cutting parameters. By using TAGUCHI optimizing the cutting parameters for the considered DOE.

Key words: Aluminium alloy ADC 12 material, Taguchi Method, Surface Roughness, CNC turning machine.

1. INTRODUCTION

Increasing the productivity and the quality of the machined parts are the main challenges of metal-based industry; there has been increased interest in monitoring all aspects of the machining process. Turning is the most widely used among all the cutting processes. The increasing importance of turning operations is gaining new dimensions in the present industrial age, in which the growing competition calls for all the efforts to be directed towards the economical manufacture of machined parts and surface finish is one of the most critical quality measures in mechanical products.

Machining operations have been the core of the manufacturing industry since the industrial revolution [1]. The existing optimization researches for computer numerical controlled (CNC) turning were either simulated within particular manufacturing circumstances [2–5] or achieved through numerous frequent equipment operations 6.Nevertheless, these are regarded as computing simulations, and the applicability to real-world industry is still uncertain. Therefore, a general deduction optimization scheme without equipment operations is deemed to be necessarily developed. The machining process on a CNC lathe is programmed by speed, feed rate, and cutting depth, which are frequently determined based on the job shop experiences. However, the machine performance and the product characteristics are not guaranteed to be acceptable. Therefore, the optimum turning conditions have to be accomplished. It is mentioned that the tool nose runoff will affect the performance of the machining process .Therefore, the tool nose runoff is also selected as one of the control factors in this study. Manufacturing enterprises presently have to deal with growing demands for improved product quality, greater product unpredictability, shorter product life-cycles, cheap cost, and global struggle . In the field of machining, manufacturers are turning increasingly more often to automation as an effective way to meet these demands. A solution issue for an unattended and automated machining system is the development of reliable and robust monitoring systems. Turning is the removal of metal from the outer diameter of a rotating cylindrical workpiece

AL-Alloy: Pure aluminium is soft, ductile, and corrosion resistant and has a high electrical conductivity. It is widely used forfoil and conductor cables, but alloying with other elements is necessary to provide the higher strengths needed for other applications. Aluminium is one of the lightest engineering metals, having a strength to weight ratio superior to steel. By utilising various combinations of its advantageous properties such as strength, lightness, corrosion resistance, recyclability and formability, aluminium is being employed in an ever-increasing number of applications.

ALUMINIUM ALLOY ADC12

The chemical composition and mechanical properties of aluminum alloy ADC12 as shown in table 1.1 and 1.2

Element ADC12	Cu	Mg	Si	Fe	Mn	Zn	Sn	Ni	Other impurities each total	Aluminium
%	1.5 - 3.5	0.3 max	9.6 - 12	1.3 max	0.5 max	1 max	0.3 max	0.5 max	0.05max 0.15max	Remainder

Table 1.1: Chemical composition of Aluminum alloy ADC12

Designation	Density (g/cm3)	Heat Capacity (J/g.K)	Thermal Conductivity (W/m.K)	Melting Range (℃)	Tensile Strength, Ultimate (MPa)	Tensile Strength,Yield (MPa)	Elongation (%)
ADC12	2.82	0.963	92	516-582	331	165	2.5

Table 1.2: Mechanical properties of Aluminum alloy ADC12

2. LITERATURE REVIEW

Traditionally, the selection of cutting conditions for metal cutting is left to the machine operator. since turning is the primary operation is most of the production process in the industry, surface finish of turned components has greater influence on the quality of the product. In such cases, the experience of operators play a major role, but even for a skilled operator it is very difficult to attain optimum values each time. The main machining parameters in metal turning operation are cutting speed, feed and depth of cut etc.

The setting of these parameters not only increases the utility for machining economies, but also the product quality increase to a great extent. In this context an effort has been made to estimate the surface roughness using experimental data. Different procedures have been used by researchers from time to time for the process of optimization. The present work is an including attempt to the following verified reviews. In this chapter, the available published information on various aspects of high speed turning operation has been reviewed and presented Navneet K. prajapati [1] this paper outlines an experimental study to optimize and study the effects of process parameters in CNC turning on Surface roughness and material removal rate of SS 316 (austenite steel) work material in dry environment conditions.

It states Feed rate is found the most significant effect on surface roughness. Increase in feed rate, value of surface roughness is increase. Increase in cutting speed, value of surface roughness is decrease. Increase in depth of cut value of surface roughness is increase. The optimal combination of low feed rate and low depth of cut with high cutting speed is beneficial for reducing machining force so surface roughness is decrease when high cutting speed, low feed rate and low depth of cut .

Harish kumar,Mohd Abbas,Dr.Aas Mohammad[2] This paper attempts to introduce and thus verifies experimentally as to how the Taguchi parameter could be used in identify the significant process parameters and optimizing the surface roughness in the turning operation and experimentally verify that the Taguchi approach gives us the optimal parameters in the CNC turning process using High Speed Steel cutting tools the optimum set of speed, feed rate and depth of cut and the most affecting parameters having the impact of 59.9% is Speed.

K.Vinaykumar, Y.Rameswara Reddy [3]. In this work a second order polynomial equation model is developed to predict the surface roughness. Surface roughness, for that it is required to optimize the turning parameters. Taguchi method is one of the Optimization techniques for optimizing the cutting parameters. By using Taguchi method, optimizing the cutting parameters for the considered DOE.

Among the cutting parameters speed has the great influence, followed by the combined effect of speed and feed, feed, depth of cut, feed and depth of cut and speed and depth of cut. Second order polynomial equation is generated based on the experimental values and predicted the surface roughness values. Then compared the predicted surface roughness values with the experimental values and found that generated equation has better capability for predicting the surface roughness values.

C R Barik, N K Mandal[4]. This paper presents an experimental study of roughness characteristics of surface roughness generated in CNC turning of EN 31 alloy steel and optimization of machining parameters based on Genetic Algorithm. It is seen that the surface roughness parameter decreases with increase in spindle speed and depth of cut but increases with increase in feed rate. The adequacy of the models of surface roughness has been established with the analysis of variance (ANOVA). And finally for optimizing the cutting parameters, Genetic Algorithm process has been implied to achieve minimum surface roughness.

kamal hasan, Anil Kumar, M.P.Garg.[5].This study investigates the effects of process parameters on Material Removal Rate (MRR) in turning of C34000. The single response optimization problems i.e. optimization of MRR is solved by using Taguchi method. The optimum levels of process parameters for simultaneous optimization of MRR have been identified. Optimal results were verified through confirmation experiments.

Jakhale prashant P, Jadhav B. R [6], in this stage, The experiments have been conducted using L9 orthogonal array in a TACCHI lathe CNC turning machine. Turning process carried out on the high alloy steel(280 BHN).The optimum cutting condition was determined by using the statistical methods of signal-to-noise (S/N) ratio and the effect of cutting parameters and insert type on surface roughness were evaluated by the analysis of variance (ANOVA). In the present experimental work, multi response optimization problem has been solved by obtaining an optimal parametric combination, capable of producing high surface quality turned product in a relatively lesser time.

3. SURFACE ROUGHNESS

Surface quality is a very essential requirement for many machined products. Any metal cutting processes are not only to shape machine components but also to produce a good dimensional accuracy, good geometric shape and fine surface.

Now a days there are an increasing demand of most quality products. Because of the increasing demand for quality products, manufacturing engineers are facing with the difficulties of increasing productivity without compromising quality. Notably, precision machine components require accurate processes. High precision machine tools and cutting tools are being manufactured for this purpose which can be used at high speeds. These machine tools can be sensitively controlled by a computer. In the same way, the machining quality must be controlled.

Factors Affecting the Surface roughness

Whenever two machined surfaces come in contact with one another the surface quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors . These factors are explained below.

The major machining variables which affect the surface roughness are

- Speed
- Feed
- Depth of cut

The speed is defined as the rate of traverse of work surface past the cutting edge, designated as cutting velocity. It is normally expressed in terms of surface speed “meter per minute” In turning it is defined with respect to work piece since work piece is rotating.

The cutting speed is given by

$$N_c = \frac{\Pi DV}{1000} \qquad (3.2)$$

V = Rotational Speed in rev/min
D = Diameter of work piece
Which gives the rotational speed V (rev / min)

$$V = \frac{(1000 N_c)}{(\Pi D)} \qquad (3.3)$$

The feed is defined as on the translating displacement of the cutting edge of the tool along work surface during given period of time. Normally, it is expressed in term of mm per revolution.

In turning feed is measured mm/rev of work piece

$$V^f = f \times V \qquad (3.4)$$

V_f = Feed rate (mm/min)
Ƒ = Feed per rotation (mm)

The surface roughness increases with increases of feed rate. The longer the feed, which increases the separation between feed marks, leading to an increase in the value of surface roughness and is shown in figure 3.3.

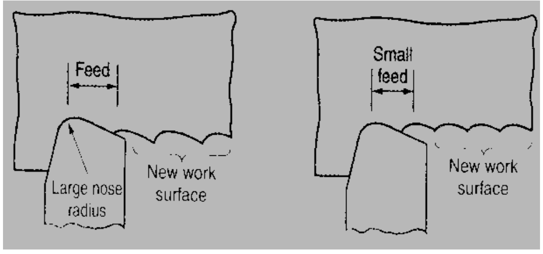


Fig.3.1: Effect of feed rate on surface roughness

Depth of cut is perpendicular distance between the atmospheric surface and generated surface of the work piece being projection of the cutting measured on the reference plane. In the case of turning diameter of the work is reduced by two times the depths of cut because this longer removal from both side of the work. The depth of cut influences the surface quality in the direct way.

The various other factors which affect surface roughness are tool geometry, work piece and tool material combination and their mechanical properties, Quality and type of the machine tool used, auxiliary tooling and lubricant used and Chatter or vibrations between the work piece,machine tool and cutting tool [1].

4. DESIGN OF EXPERIMENTS:

This branch of applied statistics deals with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters.

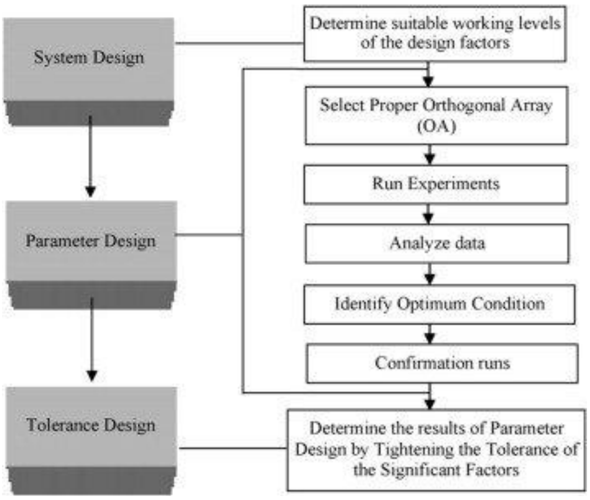
The Design of Experiments is considered as one of the most comprehensive approach in product/process developments. It is a statistical approach that attempts to provide a predictive knowledge of a complex, multi-variable process with few trials. Following are the major approaches to DOE Design of experiments is a powerful analysis tool for modelling and analysing the influence of control factors on performance output. The traditional experimental design is difficult to be used especially when dealing with large number of experiments and when the number of machining parameter is increasing. The most important stage in the design of experiment lies in the selection of the control factors. Therefore, the Taguchi method, which is developed by Dr. Genichi Taguchi, is introduced as an experimental technique which provides the reduction of experimental number by using orthogonal arrays and minimizing the effects out of control factors. Taguchi is a method which includes a plan of experiments with the objective of acquiring data in a controlled way, executing these experiments and analysis data in order to obtain the information about behaviour of the given

Process [1]. Besides that, it is a set of methodologies that took into account of the inherent variability of materials and manufacturing process during the design stage. It is almost similar to the design of experiment

(DOE) but the Taguchi design's balanced (orthogonal) experimental combination offers more effective technique than the fractional factorial design. This technique has been applied in the manufacturing processes to solve the most confusing problems especially to observe the degree of influence of the control factors and in the determination of optimal set of conditions [1].

In the Taguchi definition, the quality of a product is defined in terms of the loss imparted by the product to the society from the time it is shipped to the customer. The losses due to the functional variation are known as losses due to the deviation of the product's functional characteristics from its desired target value. Besides that, the noise factors are the uncontrollable factors which cause the functional characteristics of a product that do not achieve its targeted values. The noise factors can be classified as the external factors (temperature and human errors), manufacturing imperfections and product deterioration. The main purpose of quality engineering is to make sure that the product can be robust with the respect of all possible noise factors. So, the Taguchi method could decrease the experimental or product cycle time, reduce the cost while increasing the profit and determines the significant factors in a shorter time period as it can ensure the quality in the design phase.

The procedure of Taguchi's design as shown in Fig. 1 can be categorized into three stages viz. system design, parameter design and tolerance design. Parameter design, considered as the most important stage, can determine the factors affecting quality characteristics in the manufacturing process. The first step in Taguchi's parameter design is selecting the proper orthogonal array (OA) according to the controllable factors (parameters). Then, experiments are run according to the OA set earlier and the experimental data are analysed to identify the optimum condition. Once the optimum conditions are identified, then confirmation runs are conducted with the identified optimum levels of all the parameters



The S/N ratio can be characterized into three categories when the characteristics are continuous: Nominal is the best characteristic

$$S/N = 10\log\frac{\bar{y}}{S_y^2}$$

Smaller the better characteristic

$$S/N = 10\log\frac{1}{n}\left(\sum y^2\right)$$

Larger the better characteristics

$$S/N = 10\log\frac{1}{n}\left(\sum\frac{1}{y^2}\right)$$

where '$\bar{y}$' is the average observed data, 'S_y^2' the variance of 'y', 'n' the number of observations, and 'y' the observed data. For each type of characteristics, higher or lower value of S/N ratio indicates the better result value

Steps In Taguchi Methodology

1. **Determine the Quality Characteristic to be optimized**
   The first step in the Taguchi method is to determine the quality characteristic to be optimized. The quality characteristic is a parameter whose variation has a critical effect on product quality. It is output or the response variable to be observed. Examples are weight, cost, corrosion, target thickness, surface roughness, strength of a structure, and electromagnetic radiation etc.

2. **Identify the Noise Factors and Test Conditions**
   The next step is to identify the noise factors that can have a negative impact on system performance and quality. Noise factors are those parameters which are either uncontrollable or are too expensive to control. Noise factors include variations in environmental operating conditions, deterioration of components with usage, and variation in response between products of same design with the same input.

3. **Identify the Control Parameters and Their Alternative Levels**
   The third step is to identify the control parameters thought to have significant effects on the quality characteristic. Control parameters are those design factors that can be set and maintained. The levels for each test parameter must be chosen at this point. The number of levels, with associated test values, for each test parameter defines the experimental region.

4. **Design the Matrix Experiment and Define the Data Analysis Procedure**
   The next step is to design the matrix experiment and define the data analysis procedure. First, the appropriate orthogonal arrays for the noise and control parameters to fit a specific study are selected. Taguchi provides many standard orthogonal arrays and corresponding linear graphs for this purpose. After selecting the appropriate orthogonal arrays, a procedure to simulate the variation in the quality characteristic due to the noise factors needs to be defined. A common approach is the use of Monte Carlo simulation. However, for an accurate estimation of the mean and variance, Monte Carlo simulation requires a large number of testing conditions which can be expensive and time consuming. As an alternative, Taguchi proposes orthogonal array based simulation to evaluate the mean and the variance of a product response resulting from variations in noise factors as shown in fig. the results of the experiment for each combination of control and noise array experiment are denoted by `Yii`.

5. **Conduct the Matrix Experiment**
   The next step is to conduct the matrix experiment and record the results. The Taguchi method can be used in any situation where there is a controllable process. The controllable process can be an actual hardware experiment, systems of mathematical equations, or computer models that can adequately model the response of many products and processes. Analyze the Data and Determine the Optimum Levels After the experiments have been conducted, the optimal test parameter configuration within the experiment design must be determined. To analyze the results, the Taguchi method sues a statistical measure of performance called signal-to-noise (S/N) ratio borrowed from electrical control theory. The S/N ratio developed by Dr.Taguchi is a performance measure to choose control levels that best cope with noise. The S/N ratio takes both the mean and the variability into account. In its simplest form S/N ratio is the ratio of the mean (signal) to the standard deviation (noise). The S/N equation depends on the criterion for the quality characteristic to be optimized. While there are many different possible S/N ratios, three of them are considered standard and are generally applicable in the situations below. Predict the Performance at these Levels Using the Taguchi method for parameter design, the predicted optimum setting need not correspond to one of the rows of the matrix experiment. This is often the case when highly fractioned designs are used therefore, as the final step an experimental confirmation is run using the predicted optimum levels for the control parameters being studied.

ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance (ANOVA) is a statistical method for determining the existence of differences among several population means. While the aim of ANOVA is the detect differences among several populations means, the technique requires the analysis of different forms of variance associated with the random samples under study- hence the name analysis of variance. The original ideas analysis of variance was developed by the English Statistician Sir Ronald A. Fisher during the first part of this century. Much of the early work in this area dealt with agricultural experiments where crops were given different treatments, such as being grown using different kinds of fertilizers. The researchers wanted to determine whether all treatments under study were equally effective or whether some treatments were better than others. Better referred to those treatments that would produce crops of greater average weight. This question is answered by the analysis of variance.

5. EXPERIMENTAL DESIGN

A full-factorial design is considered to include three controlled factors (turning parameters) and a response variable. The response variable is surface roughness, measured in micrometers. The controlled factors include the three major turning parametersare:

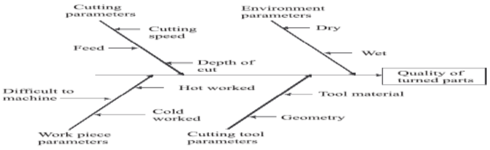


Fig: 5.1 Cause and Effect Diagram

- Cutting speed(rpm)
- Feed(mm/min)
- Depth of cut(mm)

The cutting tool specifications, details of CNC Turing Machine, Design of Experiments, and Taguchi Methodology are discussed in the following sections.

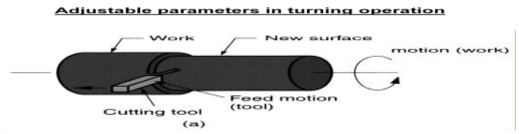


FIG.5.2: Turning Operation

5.1 CUTTING TOOL SPECIFICATIONS

For machining ADC12 tool is carbide tool is used. Nose radius of the tool is 0.4 mm

C N M G 12 04 04 –MF2 1000 T
1 2 3 4 5 6 7

1. → Insert shape
2. → Insert clearance angle
3. → Tolerances
4. → Insert type
5. → Insert size = Cutting edge length / mm
6. → Insert thickness(S), mm = 0.4 mm
7. → Nose radius(r), mm= 0.4 mm

MF2 1000 T → Manufacturer's Code

5.2 MACHINE SPECIFICATIONS (CNC Turning Machine)

The various specifications of the turning machine, used in the present work are given in the Table 5.1. Fig 5.2 shows the front view of CNC Turning Machine used for the present work. The experiments have been carried out on CNC turning machine. The raw material considered are ADC12 aluminum alloy.

The work pieces samples of size 50 mm lengths and 23 mm diameter is prepared from the 900mm length of 30 mm diameter bar. Totally 14 samples of 50 mm length and 23 mm diameter pieces were used for further machining.

Table 5.1: CNC Turning Machine (STAR TURN) Specifications

CHUCK SIZE	80mm
MAXIMUM TURNING DIAMETER	32mm
MAXIMUM TURNING LENGTH	120mm
NO. OF AXES	2
SWING OVER BED	150mm
SWING OVER CROSS SLIDE	50mm
DISTANCE BETWEEN CENTERS FROM SPINDLE SPACE	210mm
HOLE THROUGH SPINDLE	20mm
SPINDLE SPEED RANGE	150-1000rpm

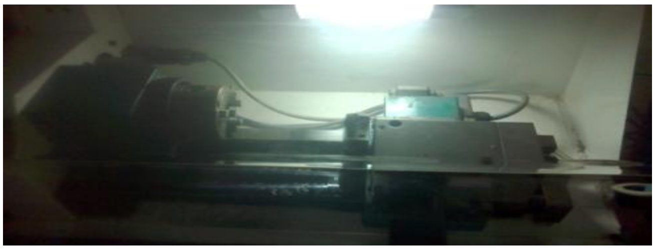


Fig.5.3: Front Side View of the CNC Lathe

5.3 ROUGHNESS MEASUREMENT

Roughness measurement has been done using a portable stylus-type profilometer, *Talysurf* . The Talysurfinstrument (Surtronic 3+) is a portable, self-contained instrument for the measurement of surface texture. The parameter evaluations are microprocessor based. The measurement results are displayed on an LCD screen and can be output to an optional printer or anothercomputer for further evaluation. The instrument is powered by non-rechargeable alkaline battery (9V). It is equipped with a diamond stylus having a tip radius 5 μm. The measuring stroke always starts from the extreme outward position. Surface roughness measurement with the help of stylus has been shown in Figure 5.4.

Fig.5.4: Photographic view of stylus during surface roughness measurement

5.4 LINE PROGRAM:

```
N10           G21      G98;
N20           G28      U0 W0;
N30           M06      T5;
N40           M03      S300;
N50           G00      X13     Z0;
N60           G90      X11.5   Z-25    F10;
N70           G28      U0      W0;
N80           M05      M30;
```

5.5 DESIGN OF EXPERIMENTS

The mathematical modeling of surface roughness models for a particular work and tool material involved a large number of other factors, such as ways of holding the work piece, the geometry of cutting tool, tool wear, chatter or vibrations of the machine tool, inaccuracies in machine tool movements, irregularities in the feed mechanism, defects in the structure of the work material, discontinuous chip formation. However only three dominant factors were considered in the planning of the experiment. The factors considered were depth of cut, feed rate, and cutting speed. The following range of values was taken for the each factor.

Table 5.2: Different Levels of Input Parameters

Input Parameters	Levels of Input Parameters		
Speed	300(N1)	450(N2)	600(N3)
Feed	0.10(F1)	0.13(F2)	0.16(F3)
Depth Of Cut	0.5(DOC1)	0.75(DOC2)	1.00(DOC3)

Based on the settings, total 27 experiments, each having a combination of different levels of factors as shown in Table 5.2, will be carried out and the response of surface roughness will be measured.

Table 5.3: Factorial Design Matrix

RUN	N	F	DOC		RUN	N	F	DOC
1	N1	F1	DOC1		14	N2	F2	DOC1
2	N1	F1	DOC2		15	N2	F2	DOC2
3	N1	F1	DOC3		16	N2	F3	DOC3
4	N1	F2	DOC1		17	N2	F3	DOC1
5	N1	F2	DOC2		18	N2	F3	DOC2
6	N1	F2	DOC3		19	N3	F1	DOC3
7	N1	F3	DOC1		20	N3	F1	DOC1
8	N1	F3	DOC2		21	N3	F1	DOC2
9	N1	F3	DOC3		22	N3	F2	DOC3
10	N2	F1	DOC1		23	N3	F2	DOC2
11	N2	F1	DOC2		24	N3	F2	DOC3
12	N2	F1	DOC3		25	N3	F3	DOC1
13	N2	F2	DOC1		26	N3	F3	DOC2
					27	N3	F3	DOC3

The experiment has been conducted on each sample of 50mm length and 23mm diameter piece, considering 24mm length for each experiment as per the DOE. The response variable, surface roughness is measured using Pocket Surftest Stylus Profilometer. The surface roughness is measured randomly three times on the surface and the average of the value is taken. The various values of the experimentation are shown in the Table 5.4.

Table 5.4: Experimental Data AA-ADC12

s.no.	N (m/min)	Feed(mm/rev)	DOC (mm)	Ra (μm)	S/N Ratio
1	300	0.1	0.5	0.87	1.20
2	300	0.1	0.75	1.29	-2.21
3	300	0.1	1.00	1.19	-1.51
4	300	0.13	0.5	1.13	-1.06
5	300	0.13	0.75	0.71	2.97
6	300	0.13	1.00	0.75	2.49
7	300	0.16	0.5	1.37	-2.73
8	300	0.16	0.75	1.09	-0.74
9	300	0.16	1.00	0.92	0.72
10	450	0.1	0.5	1.22	-1.72
11	450	0.1	0.75	1.10	-0.82

12	450	0.1	1.00	1.37	-2.73
13	450	0.13	0.5	1.38	-2.79
14	450	0.13	0.75	0.73	2.73
15	450	0.13	1.00	1.57	-3.91
16	450	0.16	0.5	1.30	-2.27
17	450	0.16	0.75	1.27	-2.07
18	450	0.16	1.00	1.56	-3.86
19	600	0.1	0.5	0.98	0.17
20	600	0.1	0.75	1.05	-0.42
21	600	0.1	1.00	1.02	-0.17
22	600	0.13	0.5	1.28	-2.14
23	600	0.13	0.75	1.35	-2.60
24	600	0.13	1.00	1.20	-1.58
25	600	0.16	0.5	1.65	-4.34
26	600	0.16	0.75	1.69	-4.55
27	600	0.16	1.00	1.19	-1.51

5.6 Taguchi Methodology

Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipment, and facilities. These improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best results. Taguchi proposed a standard procedure for applying his method for optimizing any process.

1. Determine the quality characteristic to be optimized
2. Identify the noise factors and test conditions
3. Identify the control factors and their alternative levels
4. Design the matrix experiment and define the Data analysis procedure
5. Conduct the matrix experiment
6. Analyze the data and determine optimum Levels for control factors
7. Predict the performance at these levels

6. RESULTS AND DISCUSSION

6.1 Analysis of Results

6.1.1Estimation of mean signal to Noise ratio

Mean signal to noise ratio cutting speed

$$m_{sn} = \frac{(\eta 1+\eta 2+\eta 3+\cdots \eta 27)}{27} = -1.159$$

Mean signal to noise ratio for cutting speed at level-1

$$m_{snv1} = \frac{(\eta 1+\eta 2+\eta 3+\eta 4+\eta 5+\eta 6+\eta 7+\eta 8+\eta 9)}{9} = -1.01$$

Mean signal to noise ratio for cutting speed at level-2

$$m_{snv2} = \frac{(\eta 10+\eta 11+\eta 12+\eta 13+\eta 14+\eta 15+\eta 16+\eta 17+\eta 18)}{9} = -1.93$$

Mean signal to noise ratio for cutting speed at level-3

$$M_{snv3} = \frac{(\eta 19+\eta 20+\eta 21+\eta 22+\eta 23+\eta 24+\eta 25+\eta 26+\eta 27)}{9} = -1.904$$

Mean signal to noise ratio for Feed at level-1

$$m_{snf1} = \frac{(\eta 1+\eta 2+\eta 3+\eta 10+\eta 11+\eta 12+\eta 19+\eta 20+\eta 21)}{9} = -0.88$$

Mean signal to noise ratio for Feed at level-2

$$m_{snf2} = \frac{(\eta 4+\eta 5+\eta 6+\eta 13+\eta 14+\eta 15+\eta 22+\eta 23+\eta 24)}{9} = -0.62$$

Mean signal to noise ratio for Feed at level-3

$$m_{snf3} = \frac{(\eta 7+\eta 8+\eta 9+\eta 16+\eta 17+\eta 18+\eta 25+\eta 26+\eta 27)}{9} = -2.37$$

Mean signal to noise ratio for Depth of cut at level-1

$$m_{snd1} = \frac{(\eta 1+\eta 4+\eta 7+\eta 10+\eta 13+\eta 16+\eta 19+\eta 22+\eta 25)}{9} = -1.71$$

Mean signal to noise ratio for Depth of cut at level-2

$$m_{snd2} = \frac{(\eta 2+\eta 5+\eta 8+\eta 11+\eta 14+\eta 17+\eta 20+\eta 23+\eta 26)}{9} = -0.85$$

Mean signal to noise ratio for Depth of cut at level-3

$$m_{snd3} = \frac{(\eta 3+\eta 6+\eta 9+\eta 12+\eta 15+\eta 18+\eta 21+\eta 24+\eta 27)}{9} = -1.31$$

Table 6.1: Response table for signal to noise ratio

Level	Speed	Feed	Doc
1	-1.01	-0.88	-1.71
2	-1.93	-0.62	-0.85
3	-1.90	-2.37	-1.31
Delta	0.92	1.75	0.86
Rank	2	1	3

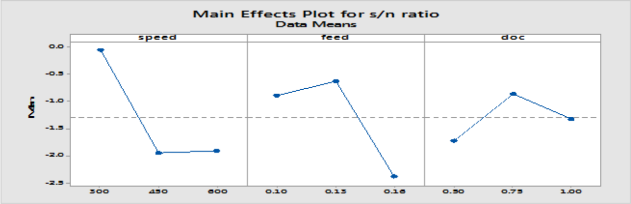


Fig 6.1: mean effective plot for S/N ratios

6.1.2Estimation of mean surface roughness

Mean surface roughness

$$m_R = \frac{(Ra\,1+Ra\,2+Ra\,3+\cdots+Ra\,27)}{27} = 1.12\mu m$$

Mean surface roughness for cutting speed at level-1

$$m_{Rv1} = \frac{(Ra\,1+Ra\,2+Ra\,3+Ra\,4+Ra\,5+Ra\,6+Ra\,7+Ra\,8+Ra\,9)}{9} = 1.03\ \mu m$$

Mean surface roughness for cutting speed at level-2

$$m_{Rv2} = \frac{(Ra\,10+Ra\,11+Ra\,12+Ra\,13+Ra\,14+Ra\,15+Ra\,16+Ra\,17+Ra\,18)}{9} = 1.27\mu m$$

Mean surface roughness for cutting speed at level-3

$$m_{Rv3} = \frac{(Ra\,19+Ra\,20+Ra\,21+Ra\,22+Ra\,23+Ra\,24+Ra\,25+Ra\,26+Ra\,27)}{9} = 1.26\mu m$$

Mean surface roughness for feed at level-1

$$m_{Rf1} = \frac{(Ra\,1+Ra\,2+Ra\,3+Ra\,10+Ra\,11+Ra\,12+Ra\,19+Ra\,20+Ra\,21)}{9} = 1.12\ \mu m$$

Mean surface roughness for feed at level-2

$$m_{Rf2} = \frac{(Ra\,4+Ra\,5+Ra\,6+Ra\,13+Ra\,14+Ra\,15+Ra\,22+Ra\,23+Ra\,24)}{9} = 1.122\mu m$$

Mean surface roughness for feed at level-3

$$m_{Rf3} = \frac{(Ra\,7+Ra\,8+Ra\,9+Ra\,16+Ra\,17+Ra\,18+Ra\,25+Ra\,26+Ra\,27)}{9} = 1.33\ \mu m$$

Mean surface roughness for depth of cut at level-1

$$m_{Rd1} = \frac{(Ra\,1+Ra\,4+Ra\,7+Ra\,10+Ra\,13+Ra\,16+Ra\,19+Ra\,22+Ra\,25)}{9} = 1.24\ \mu m$$

Mean surface roughness for depth of cut at level-2

$$m_{Rd2} = \frac{(Ra\,2+Ra\,5+Ra\,8+Ra\,11+Ra\,14+Ra\,17+Ra\,20+Ra\,23+Ra\,26)}{9} = 1.14\mu m$$

Mean surface roughness for depth of cut at level-3

$$m_{Rd3} = \frac{(Ra\,3+Ra\,6+Ra\,9+Ra\,12+Ra\,15+Ra\,18+Ra\,21+Ra\,24+Ra\,27)}{9} = 1.19\mu m$$

Level	Speed	Feed	Doc
1	1.03	1.121	1.24
2	1.26	1.122	1.14
3	1.27	1.333	1.19
Delta	0.24	0.21	0.10
Rank	1	2	3

Table 6.2: Response table for mean

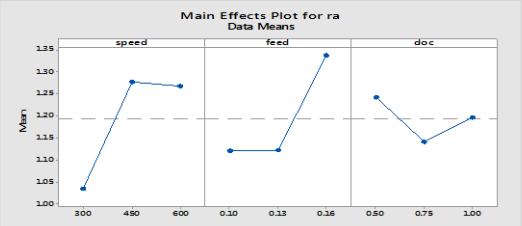


Fig 6.2: mean effects for plot Ra

6.2Analysis of Variance:

The purpose of analysis of variance (ANOVA) is to determine which turning parameters significantly affect the quality characteristic (surface roughness)

6.2.1For surface roughness

Grand total sum of squares: $\sum^{27}_{i=1} R^2_{ai}$ $= [R_{a1}^2 + R_{a2}^2 + R_{a3}^2 \ldots\ldots + R_{a27}^2]$
$= 40.30 (\mu m)$
Sum of squares of mean: $\sum_{i=1}^{27} (27 m_r^2)$ $= 27 \times 1.21^2$
$= 33.86\ (\mu m)^2$
Total sum of square: (Grand total sum of squares-Sum of squares of mean)
$= 6.44\ (\mu m)^2$
Sum of squares due to cutting speed(v):
$= 3\sum^{3}_{i=1}(m_{Rvi} - m_R)^2$ $= 0.150 (\mu m)^2$
Sum of squares due to feed:
$= 3\sum^{3}_{i=1}(m_{Rvi} - m_R)^2$ $= 0.264 (\mu m)^2$
Sum of squares due to depth of cut:
$= 3\sum^{3}_{i=1}(m_{Rfi} - m_R)^2$ $= 0.059 (\mu m)^2$

<u>Mean squares</u>
Mean_squares due to cutting speed
= (sum of squares due to cutting speed)/(degrees of freedom due to cutting speed)
$= 0.150 (\mu m)^2$
Mean_squares due to feed
= (sum of squares due to feed)/(degrees of freedom due to feed)
$= 0.264 \mu m)^2$
Mean_squares due to depth of cut
= (sum of squares due to depth of cut)/(degrees of freedom due to depth of cut)
$= 0.059 (\mu m)^2$

<u>Variance ratio</u>
Variance ratio for cutting speed
= (mean square due to cutting speed)/(mean squares error)
= 0.31
Variance ratio for feed
= (mean square due to feed)/(mean squares error)
= 0.55
Variance ratio for depth of cut
= (mean square due to depth of cut)/(mean squares error)
= 0.12

<u>Percentage of contribution</u>
% percentage contribution for cutting speed
= (sum of squares due to cutting speed)/(total sum of squares)
= 35.71%
% percentage contribution for feed
= (sum of squares due to feed)/(total sum of squares)
= 55.81%
%percentage contribution for Depth of cut

= (sum of squares due to depth of cut)/(total sum of squares)
=12.47%

S. NO	FACTORS	DOF	SUM OF SQUARES	MEAN OF SQUARES	VARIANCE	% OF CONTRIBUTION
1	CUTTING SPEED	1	0.0615	0.030	0.714	35.71
2	FEED	1	0.18	0.09	2.14	55.81
3	DEPTH OF CUT	1	0.0159	0.0079	0.18	12.47
4	ERROR	23	0.257			
5	TOTAL	26		0.042		

Table 6.3:ANOVA FOR RESPONSE OF Ra

6.3 Predicting the optimum performance and confirmation of experiment design:
The confirmation experiment is very important in parameter design ,particularly when small fractional factorial experiments are utilized. The purpose of the confirmation experiment in this study was to validate the minimum surface roughness conditions that were suggested by the experiment, which correspond with the predicted value.

Confirmation Experiment

	Optimal cutting parameters	
	Predicted	Experimental
Setting level	$V_5f_5d_5$(300 0.13 0.75)	$V_5d_5f_5$(300 0.13 0.75)
Surface Roughness value(µm)	1.077	0.71
S/N ratio(dB)	-0.405	2.97

Table 6.4: predicted values

The aim of the present work is to present find out the influence of speed, feed and depth of cut on surface roughness

- From the experiment, the influence on the response parameter surface roughness (Ra) by the cutting parameters like speed, feed, Doc is: The feed rate is having effect on surface roughness, cutting speed and depth of cut is decreasing in trend.
- The design of experiments (DOE),taguchi method is applied for the optimization of cutting parameters and analysis of variance(ANOVA) is carried out for The optimal combination of process parameters for minimum surface roughness is obtained at 300rpm cutting speed,0.13 mm/rev feed,1.0 of depth of cut.
- ANOVA shows that feed rate has great influence for the surface roughness(Ra),and its percentage contribution to the surface roughness is determined to be 55.81% significant.
- From the analysis of table it is observed that the percentage contribution of cutting speed, Feed and depth of cut are 35.71%, 55.81%, 12.47% respectively have statistical and physical significance on the surface roughness.
-

7. CONCLUSIONS

In present work, the effect of cutting speed, feed and depth of cut on surface finish on aluminum alloys ADC12 has been studied. The input parameters selected are speed in three levels, feed in three levels and depth of cut three levels. Different levels of input conditions are derived based on factorial Design of Experiments. The experiments have been conducted on CNC Turning Machine. In total 14 samples of 50 mm length and 23 mm diameter work pieces were prepared. Two experiments were carried on each specimen. Using the aluminum alloy ADC12.

In the present work, the optimum combination of cutting parameters on surface finish is obtained. Based on the experimental results it is concluded that:

- Feed is the cutting parameter that has highest physical as well as statistical influence on the surface roughness(Ra) i.e.,55.81%,next cutting speed i.e.,35.71%,next depth of cut i.e.,12.47%.
- The effect of depth of cut on the surface roughness in not regular and has a variable character

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Biography

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