# Application of ANOVA and ANN Technique for Optimize Of CNC Machining Parameters

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## *Abstract:*

In the present study, the influence of machining parameters on surface roughness and material removal rate is examined by utilizing ANN& ANOVA techniques. Three important variables i.e. spindle velocity, depth of cut and feed rate which are influence on the surface roughness and material removal rate are examined and also analyzed. Artificial Neural Network and Analysis of variance techniques are effective tools for analyze and optimize the cutting parameters. Based on taguchi, design of experiments, L27 orthogonal array was selected for conducting turning experiments. 3 factors are considered at 3 levels for orthogonal array L27 design. The experimentation has been conducted on Aluminum alloy AL 6253 using CNC turner with carbide tip tool and experimental results are taken for preparing of the ANN model. The experimental results were analyzed by using ANOVA and the regression equation for predicting the surface roughness and MRR.

**Keywords:** Surface Roughness, Material removal rate, ANN (Artificial Neural Network), ANOVA Analysis of variance and Regression modeling.

## *INTRODUCTION AND LITERRATURE REVIEW*

Material removal rate and Surface roughness are very significant factors in cutting process as one of these factors will involve in the economic justification of the process and other to decide the product quality. Turning operation is a material removal process for which is used to generate cylindrical parts by removing the extra material as shown in Fig. 1. The major process parameters in turning operation are speed, feed and depth of cut. In the present work surface roughness and material removal rate are the output responses. The Taguchi technique is used to design the experiments and to examine various process parameters (cutting velocity, feed rate and depth of cut) influence on output responses.

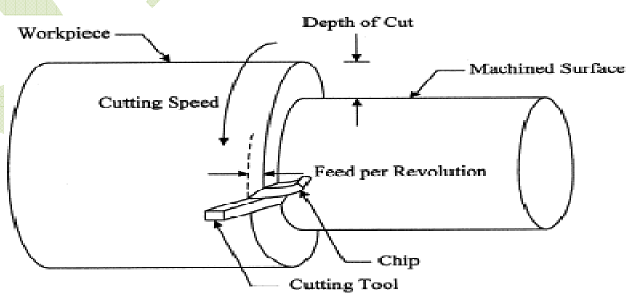



Fig. 1: Representation of figure during Turning Process

Taguchi orthogonal array (TOA) offers the way of leading the base number of investigations that gives the full data of every last one of elements that influence parameters. As per the Taguchi information, the choice of orthogonal Array (OA) depending on upon the degree of freedom (DOF) of the procedure and level of opportunity can be processed. of= (number of levels-1) for each one control factor+ (number of levels for A-1) × (number of levels for B-1)×(number of levels for C-1) for every connection + 1]. Where A, B and C are the communicating control elements [1].

Artificial neural Network (ANN) is the sequence process by using Network; they have been used in different areas of engineering problems. ANNs are used to solving non-linear and difficult problems that are not solved by numerically. Applying ANN to the process needs sufficient input and output information in the place of mathematical statement. Also, it can consistently prepare the new information among the process; therefore it can adjust to changes in the background. ANN can be used to manage issues with insufficient and loose information [2]. ANN has been developing as a simplification of technical model of human knowledge and neural science. The presented information set is divided into two sections, one related to training and the other related to validation of the model. The object of training is to conclude the position of relationship and nodal limits the region. ANN is to estimate the outputs that are adequately nearer to target values. This little of the completing records to be using for training must have satisfactory examples so that the network can follow the basic correlation among the input and output variables sufficiently [3].

M.Madic et.al [4] the advance by combination artificial neural network (ANN) and improving agreement searching algorithm (IASA) to conclude the optimal cutting constraints setting for minimize the surface roughness when turning of polymeric materials. The ANN model surface roughness is developing in conditions of cutting speed, feed rate, depth of cut, and nose radius of tool used. The data obtained from the turning experiment conduct to Taguchi's L27 orthogonal array.
Mr. Manoj Kumar Sahoo [5] report the optimize of turning process by the effect of machining parameter apply Taguchi method. Three machining parameters i.e., cutting speed, Feed rate and Depth of cut. Experiment shouldbecomplete by changeable one parameter and keep other two fixed so maximize value of each considering should be obtain. Taguchi orthogonal array is calculated with three levels of turning parameters with the help of software Minitab 16.
Julie Z. Zhang , Joseph .Chenb, et.al.[ 6] In his paper, an investigation of Taguchi outlines function to upgrade surface quality in a CNC face processing procedure. Keeping up great surface quality typically includes extra assembling expense or loss of profit. This study included feed rate, shaft velocity and depth of cut as control components. The commotion elements were the working hollow temperature and the utilization of distinctive device surrounding the same detail, which presented apparatus condition what's more dimensions are changing. An orthogonal show of L9(34) was utilized; ANOVA examines must be completed to distinguish the huge variables influencing surface unpleasantness, and the ideal cutting blending was dictated by looking for the best surface unpleasantness (reaction) and sign to-commotion degree.
S.thamizhmanii, et.al [7] The motivation behind examination paper was centered around the investigation of ideal cutting conditions to get least surface unpleasantness in turning SCM 440 combination steel by Taguchi strategy. The technique is force device for outline of top notch frameworks. It gives basic, productive furthermore careful methodology to upgrade outline for execution, quality and expense. Taguchi technique is effective technique for outlining process that works reliably and ideally over a mixed bag of conditions. To focus the best outline it helps the utilization of purposely plan test.
V.n.gaitonde, et.al. [8] Has created the application of Taguchi technique and useful idea for upgrading the machining parameters in turning of liberated-machining steel utilizing an established carbide instrument has depicted. A setting of ideal procedure parameters, for example, feed rate cutting velocity and depth of cut on two numerous execution qualities to be specific, surface roughness and metal removal rate (MRR) is created. The tests were arranged according to L9 orthogonal collection. The ideal levels of the procedure parameters was departed set during the dissection of means .The Relation vitality between the method parameters was distinguished during the dissection of difference (ANOVA).The ANOVA results showed that most critical methodology parameter is cutting velocity took after by profundity of cut that influenced the streamlining of various execution qualities. The

improvement results uncovered that a combo of larger amounts of cutting pace and depth of cut alongside feed rate in the medium level is crucial keeping in mind the end goal at the same time minimize the surface roughness and to improvement the MRR.

The objective of the present work is to enhance the process parameters in Turning of Aluminum 6253 with Taguchi method furthermore study the importance of each of process parameter along with analysis of variance (ANOVA) and Artificial neural network (ANN). The present work, MINITAB 16 is statistical analysis software was utilized for the design and study of experiments to perform the Taguchi and analysis of variance. In this work, the process parameters are optimized in Turning of Aluminum 6253 utilized Taguchi and design of experimental technique and the results are analyzed with analysis of variance technique to identify the percentage involving of each parameter on thrust force, torque and surface finish of the hole.

***METHODOLOGY***

***Taguchi method***

Taguchi developed a particular design of orthogonal arrays to study the whole parameter space with a little amount of experiments. Then transformed the experimental results to taken with a signal-to-noise(S/N) ratio. It utilizes the signal to noise percentage to estimate of quality characteristics dissimilar from nearing to the preferred values. S/N ratios are three types of excellence characters, i.e. the smaller is the better, the higher is the better, and the nominal is the finest. The formula utilized to designed for analyze S/N percentage, it is shown below.

**Smaller -is-better:**

It is utilized where the smaller value is desired. For turning process surface roughness should be low for better quality; hence smaller S/N ratios are measured for these parameters.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n} y_i^2 \quad (1)$$

Where $y_i$= observation of responding value and $n$ = number of imitations.

**Nominal-is- finest**: It is utilized the nominal or object value and difference as regards the value is nominal is the smallest.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{\mu^2}{\sigma^2} \quad (2)$$

Where μ = mean and $\sigma$ = variance.

**Higher-is-better**: It is utilized where the bigger value is preferred; in turning operation MMR should be higher.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y^2} \quad (3)$$

Where $y_i$= observed react value and $n$ = quantity of imitations.

Taguchi recommended a standard methodology for optimizing any process parameters, the steps involved in Taguchi are

- Determination of the excellence quality to be optimized.
- Identification of the smash factors and test conditions.
- Identification of control variables and their option levels.
- Designing the matrix testing in addition to significant the information analysis procedure.
- Conducting the matrix test.
- Analyzing the information furthermore determining the best possible levels ofcontrol variables.
- Predicting the recital by these levels.[9]

***ANOVA***

ANOVA is a statistical method for influential the degree of dissimilarity or similarity between two or more collections of information. It is focused around the correlation of the normal estimation of a typical segment. ANOVA is not a difficult process along with many mathematical beauty related with it. Analysis of variance is a statistically based, on object resolution making tool used for identify any divergence in standard performing of collections of objects are testing. The resolution, moderately than utilizing pure decision, receive variant into description. [10].

The sum of squares equation may be written as,

$$SS_T = SS_A + SS_B + SS_{A\times B} + SS_e$$

Where $SS_T$ = sum of squares due to total variation.

The total variation is,

$$SS_T = \left[\sum_{i=1}^{N} Y_i^2\right] - \frac{T^2}{N}$$

Where $y_i$ = i[th] observation and N= total number of samples or observations.

The general formula for any number of levels of factor A and B is,

Sum of squares of factor A, $$SS_A = \left[\sum_{i=1}^{k_A}\left(\frac{A_i^2}{n_{A_i}}\right)\right] - \frac{T^2}{N}$$

Where $k_A$ = number of levels for factor A and $n_{A_i}$= sample size under conditions $A_i$.

$$SS_B = \left[\sum_{i=1}^{k_B}\left(\frac{B_i^2}{n_{B_i}}\right)\right] - \frac{T^2}{N}$$

Where T= sum of all observations and $n_{B_i}$= sample size under conditions $B_i$.

The sum of data under the i[th] condition of the combination of factor A and B is,

$$SS_{A\times B} = \left[\sum_{i=1}^{c}\left(\frac{(A\times B)_i^2}{n_{A\times B_i}}\right)\right] - \frac{T^2}{N} - SS_A - SS_B$$

The sum of square error is,

$$SS_e = SS_T - SS_A - SS_B - SS_{A\times B}$$

***Selection of process parameters***

For the present analysis, the machining parameters like speed, feed and depth of cut of turning process to be considered. As indicated by Taguchi's outline of investigations for three parameter design and three levels L27orthogonal array be chosen. The quality of their variables and their related levels are represented in table 1

Table .1: Preferred Ranges of level for Turning

| **S.No** | **Parameters** | **Level** | | |
|---|---|---|---|---|
| | | **I** | **II** | **III** |
| 1 | Cutting speed(rpm) X | 500 | 1000 | 1500 |
| 2 | Feed rate(mm/min) Y | 10 | 40 | 70 |
| 3 | Depth of cut (mm) Z | 0.2 | 0.5 | 0.8 |

***Experimental work***

Aluminum 6253 is used as work piece material with the size of 30 mm diameter and 55 mm length. Taguchi's L27 orthogonal array was used to performing the Turning experiments as shown in Table (3)on Aluminum 6253through the solid carbide tipped tool. Chemical composition of Aluminum 6253 is represent in Table (2) and the mechanical properties of Aluminum 6253 density is 1054.5(kg/m$^3$), tensile strength is 400 Mpa, yield stress is 350 Mpa, modulus of elasticity 50-100 Mpa and also hardness is 45 HRC etc.

Table 2: Composition of Aluminum 6253

| Si | Co | Cr |
|---|---|---|
| 0.7 | 0.10% | 0.04-0.35% |
| Mg | Al | Zi |
| 1.0-1.5% | 95-97.4% | 1.6-2.4% |

There has been in increases in the research interest in the applications of ANOVA and ANN modeling the relations among the cutting conditions on the process limitations during the machining. The input parameters both the models being the speed, feed and depth of cut and the output parameters like material removal rate (MRR) and surface roughness. The experimentations are conducting on a great and exact 3-axis CNC perpendicular machining midpoint on perfectly. FLEXTURN MTAB available at Madanapalle Institute of Technology and Science, Madanapalle the spindle speed 150-4000 rpm and the extreme shaft power of 3.7kw. The rating on feed should be usual active to a maximum of 0- 5000mm/min.


Fig 2 CNC vertical turning machine

Each experiment was carried out thrice, to minimize the experimental error. A computer numerical control (CNC) machining centre (model: FLEXTURN MTAB) was used for conducting the experiments. The material removal rate and surface roughness are measure from the instrument of digital balance meter and tally surf surface roughness meter. The experimental arrangement utilized for turning operation is shown in Fig.2. After the completion of the experimentation, surface roughness of the fine quality of turning surface roughness was measured by Mitutoyo make of surf test SJ-201 Talysurf surface profile meter. The results are confirmed in Table 3. Units are using: cutting speed – Rpm, Feed rate-mm/min, depth of cut (DOC) – mm, surface roughness Ra –μm and material removal rate MRR-mm$^3$/min.

Table 3: Taguchi's $L_{27}$ Orthogonal Array

| Exp.no | Input parameters | Output Parameters |
|---|---|---|

| | Cutting Speed -Rpm | Feed rate-mm/min | Depth of cut-mm | MRR | Ra |
|---|---|---|---|---|---|
| 1 | 500 | 10 | 0.2 | 0.1 | 1.821 |
| 2 | 500 | 10 | 0.5 | 2.9 | 0.395 |
| 3 | 500 | 10 | 0.8 | 4.7 | 0.812 |
| 4 | 500 | 40 | 0.2 | 2.3 | 0.536 |
| 5 | 500 | 40 | 0.5 | 2.8 | 0.615 |
| 6 | 500 | 40 | 0.8 | 4.7 | 0.733 |
| 7 | 500 | 70 | 0.2 | 2.4 | 1.304 |
| 8 | 500 | 70 | 0.5 | 1.5 | 1.458 |
| 9 | 500 | 70 | 0.8 | 6.6 | 1.381 |
| 10 | 1000 | 10 | 0.2 | 1.1 | 0.698 |
| 11 | 1000 | 10 | 0.5 | 2.7 | 0.864 |
| 12 | 1000 | 10 | 0.8 | 4.7 | 1.153 |
| 13 | 1000 | 40 | 0.2 | 1.2 | 0.835 |
| 14 | 1000 | 40 | 0.5 | 2.7 | 0.933 |
| 15 | 1000 | 40 | 0.8 | 4.3 | 1.085 |
| 16 | 1000 | 70 | 0.2 | 1 | 0.753 |
| 17 | 1000 | 70 | 0.5 | 2.7 | 0.703 |
| 18 | 1000 | 70 | 0.8 | 4.7 | 1.225 |
| 19 | 1500 | 10 | 0.2 | 1 | 0.897 |
| 20 | 1500 | 10 | 0.5 | 2.8 | 1.392 |
| 21 | 1500 | 10 | 0.8 | 4.8 | 0.885 |
| 22 | 1500 | 40 | 0.2 | 2.5 | 1.746 |
| 23 | 1500 | 40 | 0.5 | 1.8 | 1.969 |
| 24 | 1500 | 40 | 0.8 | 6.7 | 2.021 |
| 25 | 1500 | 70 | 0.2 | 2.3 | 1.073 |
| 26 | 1500 | 70 | 0.5 | 4 | 2.764 |
| 27 | 1500 | 70 | 0.8 | 4.9 | 3.642 |

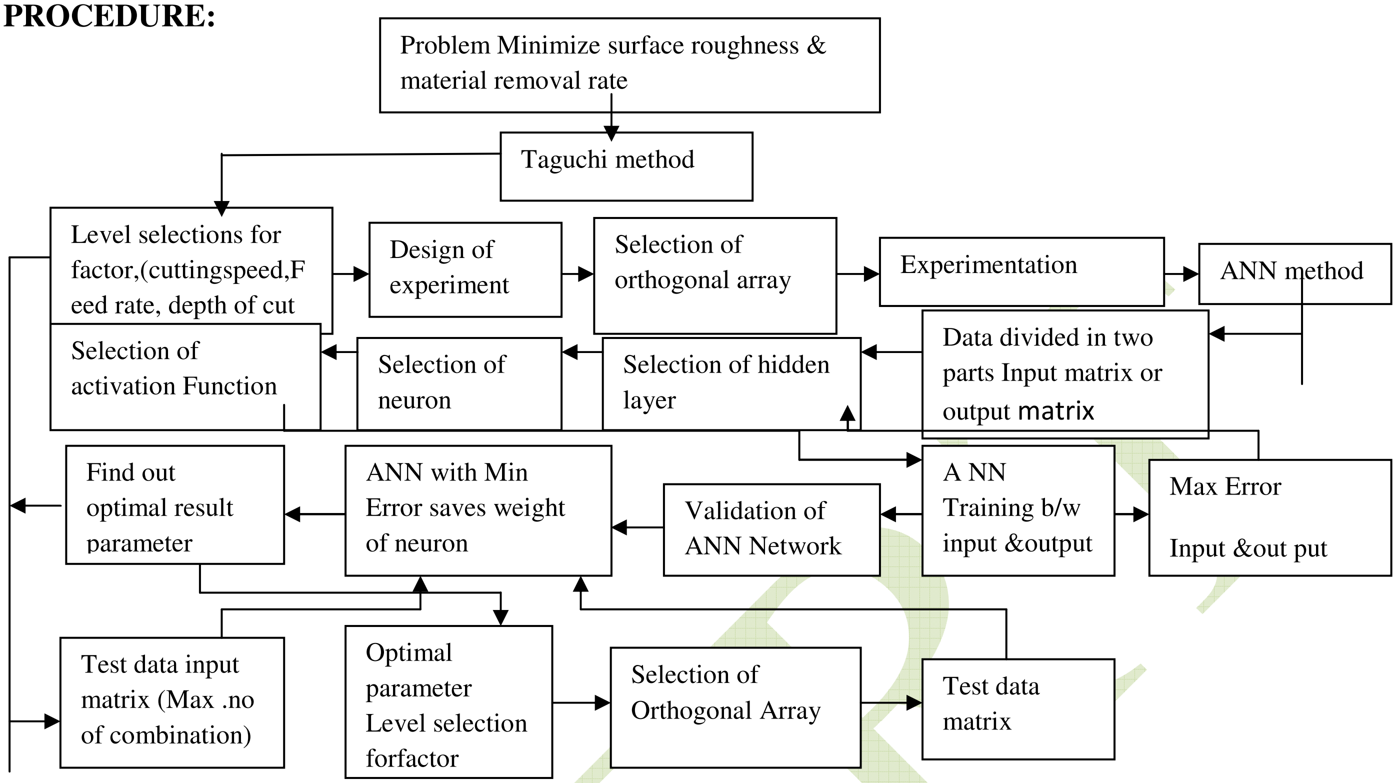
Machining is an important cutting process by remove the unwanted material from the surface of work piece by turning operation. In turning process cutting tool fed as depth of cut and provided feed parallel to the axis is of the rotation with the specified cutting speed. The object of machining operation is to machine at low surface roughness and high material removal rate of the parts. Suitable selecting of cutting parameters can create longer cutting tool life and lower surface roughness and high removal rate. A neural network is a modeling tool and it is planning model in which the brain performs a specific task or function of interest. A neural network is performing useful calculations through a process of learning. A neuron is a data preparing unit that is fundamental to the operation of a neural network. The maximum benefit of ANN is simply and speed calculation.ANN has been developed as a generally in the form of the numerical model having of human cognizance and neural biology. The present data set is divided into two parts, one for preparing and other relating to validation of the model. The principle of train is to verify the position of connecting the weights and nodal limits that cause the ANN to estimating output values that are satisfactorily near target values. This part of the completing data to be using for preparing must to containing sufficiently pattern with the therefore that the network can be hidden layer relation in the middle of input and output variables sufficiently. A back multi-layer feed forward network (MLN) is the most generally using for prediction and as a part of engineering application. A MLN commonly has an input layer, an output layer, and one or more masked layers. There are various approaches to describe the actuation purpose, for example, limit capacity, step activation purpose, twisting purpose, and hyperbolic purpose. The type of opening capacity depending upon the kind of neural network to be design. A twisting capability is generally using for the exchange capacity. The neuron in ANN is non-direct components which accept various inputs, with deliver weights, and transmitting a single output by process for a particular performance capacity. The outputs, then turns into an input feed the neurons in the following layer. The preparation methods continue pending the network output match the target i.e. the preferred output. Calculate among this inputs and target output is calling "error".

The error among the network output and the design output is minimizing by changing the weights. At the point when the mistake falls less than a decided values or the greatest number of epochs is exceed, the preparation procedure was ended. At that point this prepared network can be using for simulate the method outputs for the inputs that have not been introduce previously. The ANN (Artificial Neural Network) using for the experiment has three layers, for example, one data layer, one masked layer and another one is output layer as showing in fig. 2. The input layer, masked layer and the output layer consider of three neurons, twenty neurons and one neuron individually. The arrangement of predictive neural network with input and output parameters. Feed rates, depth of cut, cutting speed are taken as the data parameters. The output parameter is taken as the surface roughness (Ra) and material removal rate (MRR). Eighteen data are used for training set. They all are chosen randomly from [11]. Training speed and error ratio of ANN were 0.5 and 0.001, respectively. The total data having is normalize in the ranges of 0 to 1 for better generalization of ANN modeling by the process given in Eq.

$$V_N = \frac{V - V_{\min}}{V_{\max} - V_{\min}}$$

There $V_N$ is the standard estimation of a variables V (actual value in a parameter), $V_{max}$ and $V_{min}$ are the maximum and minimum values of V, separately. Training and testing data graphs and performance after 6 and 19 epochs in Mat labANN Toolbox are shown in Fig 2. Mean square error performance with respect to epochs is shown in Fig. 2the performance is finding to be 0.736462 and 2.671

**PROCEDURE:**




**NEURAL NETWORK:** The ANN indicated in fig. 3 and 4. It has three layers, one data layer, one masked layer & one Produced layer. The data layer comprises of three neurons, the produced layer comprises of one neuron, and the masked layer comprises of 20 neurons. The structure of perceptive neural system with data and give in parameters is confirmed in Fig 3 and 4. Feed rate, depth of cut, cutting velocity, is taken as the input parameters. The out parameters are taken as the surface harshness (Ra) and material removal rate (MRR). The nature of introduction capacity relies on upon the nature of neural system to be outline. A sigmoid capacity is picked for the exchange capacity. Preparing and test information illustrations and execution after 6 and 19epochs in MAT LAB NN Toolbox programming are indicated in Fig 3&4. Variety of the mean square error with preparing and test finding is 0.736462 and 2.671. The network which turned out from Taguchi technique (Design of Experiments) has been utilized for systems, then it reproduces to get yield as Fig5. From the fig 5 one can choose the base surface roughness and material removal rate on the basis of arrangement.

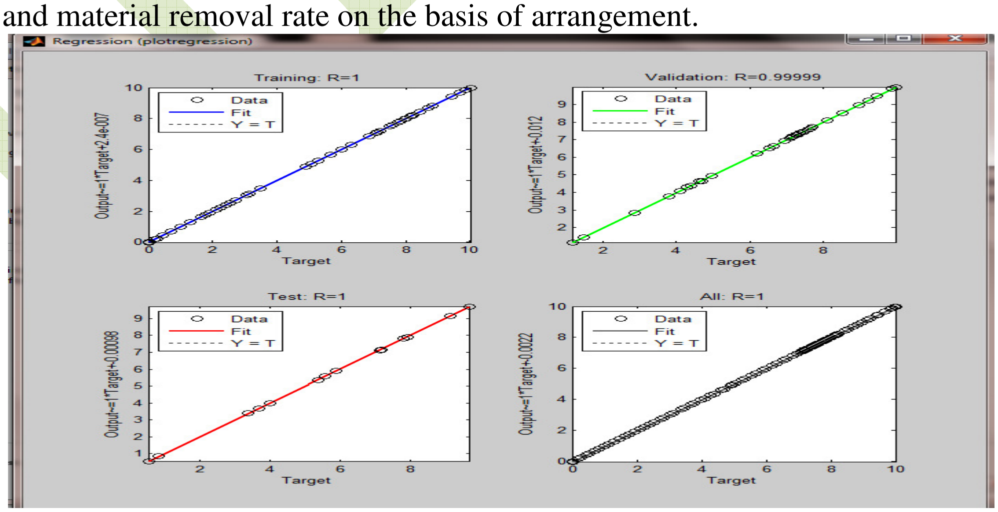



Fig. 3: Best Regression plot for Surface Roughness

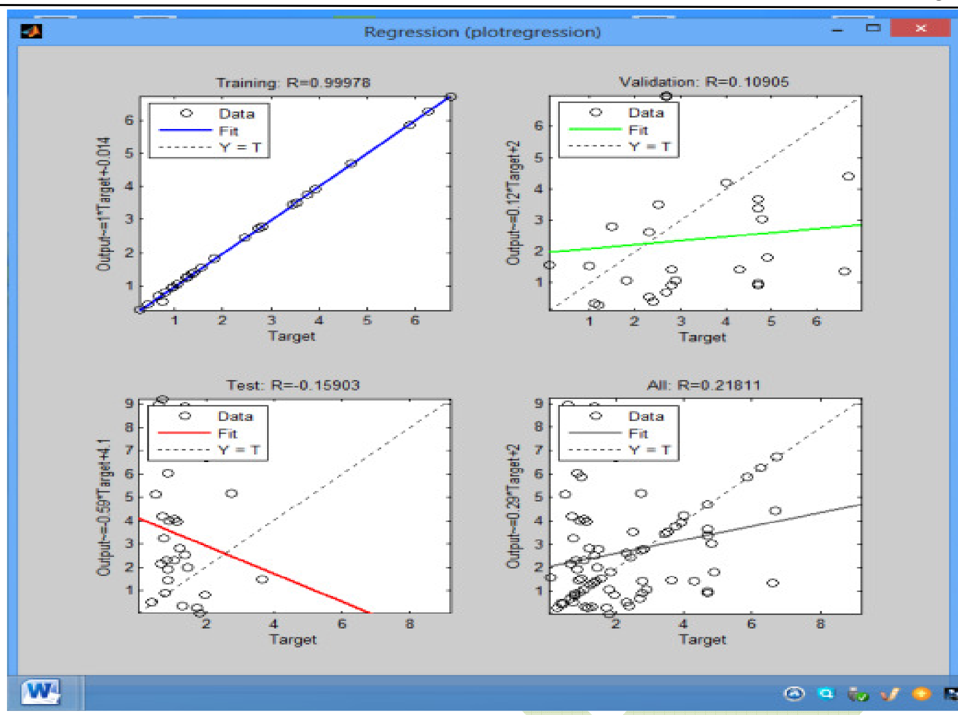



Fig 4: Best Regression plot for MRR

A decently prepared ANN is generally summed up a system is that which gives reasonable output for those input likewise which has never been experience with the networks while preparing. Preparing networks is only to locatedideal weights of the connections of two neurons. These weights, actuation capacity, number of layers and neurons in a layer choose how well nonlinearity can be characterized. After the preparation the system weights are situated and including to Fig. 4 their individuality is as takes after:

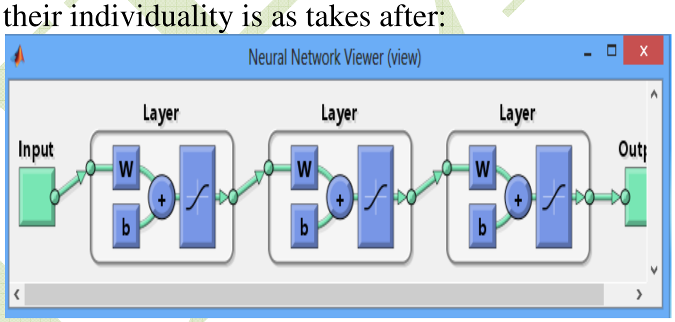



Fig. 5: The Basic Structure of the Neural Network Used For the Experiment

***Results and discussions*** The results of surface roughness, material removal rate and surface irregularity of every sample are analyzed. The experimental results were altered into S/N percentage using Eq. (1). The main effect for mean and S/N proportion is graphs within Figs. 6–7, respectively.

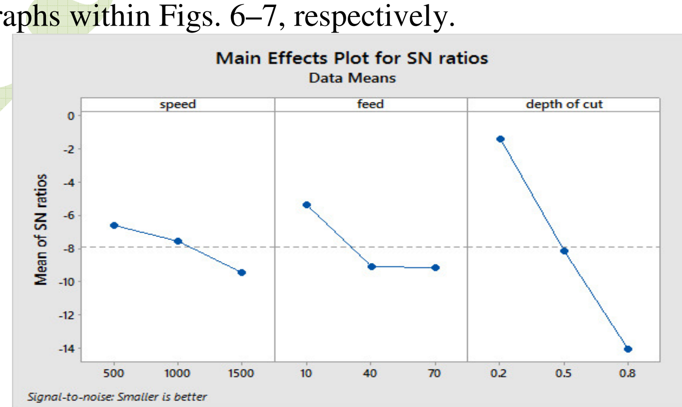


Fig .6 Most important effects plot for S/N ratio (material removal rate).

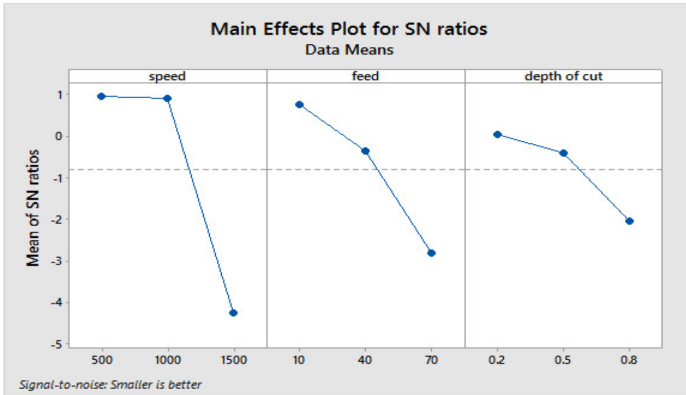



Fig .7 Most important effects plot for S/N ratio (surface roughness)

Fig. 6shows the weight of process parameters on the material removal rate. The optimum process parameters on the material removal rate are obtained as speed at level 1 (1500 rpm), feed at level 1 (70 mm/min) and depth of cut at level 3 (0.8mm)andFig. 7shows the outcome of cutting parameters on the surface roughness. The optimum process parameters on the surface roughness are to be obtains a speed at level 1 (1500 rpm), feed at level 1 (70 mm/min) and depth of cut at level 3 (0.8mm)  The degree of importance of each parameter is considered, namely speed, feed, depth of cut for each response is shown in Table respectively. Table 4, it is found that feed is the main factors are affect the material removal rate follow the depth of cut and speed. Table 5, feed and depth of cut are found to be most important factors affecting the surface roughness following by the speed. The model adequacy checking was conducted after performing an ANOVA analysis to verify the normality postulation of the residual. Fig.8,9,show constant variance, normality, independence, histogram plots , common probability plots of the residuals and these figures reveal that almost all the residuals follow a straight line pattern and this agree well with the result are reported by Davidson et al. [12]. This work will be useful for industries while the selection of process parameters in the Aluminum materials, to get better the quality of the Turning process by reducing the material removal rate and surface roughness.

Table .4  Two-way ANOVA: MRR versus feed, depth of cut

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Feed (mm/min) | 2 | 1.7385 | 0.8693 | 1.30 | 0.297 |
| Depth of cut (mm) | 2 | 60.3585 | 30.1793 | 45.07 | 0.000 |
| Interaction | 4 | 2.1881 | 0.5470 | 0.82 | 0.531 |
| Error | 18 | 12.0533 | 0.6696 | - | - |
| Total | 26 | 76.3385 | | | |

S = 0.8183R-Sq = 84.21%   R-Sq(adj) = 77.19%

Table .5 Two-way ANOVA: Ra versus feed(mm/rev), point angle(degrees)

| **Source** | **DF** | **SS** | **MS** | **F** | **P** |
|---|---|---|---|---|---|
| Feed (mm/min) | 2 | 1.7076 | 0.853801 | 1.54 | 0.240 |
| Depth of cut (mm) | 2 | 0.5971 | 0.298575 | 0.54 | 0.592 |
| Interaction | 4 | 1.2257 | 0.306428 | 0.55 | 0.699 |
| Error | 18 | 9.9516 | 0.552865 | | |
| Total | 26 | 13.4820 | | | |

S = 0.7435R-Sq = 26.19% R-Sq(adj) = 0.00%

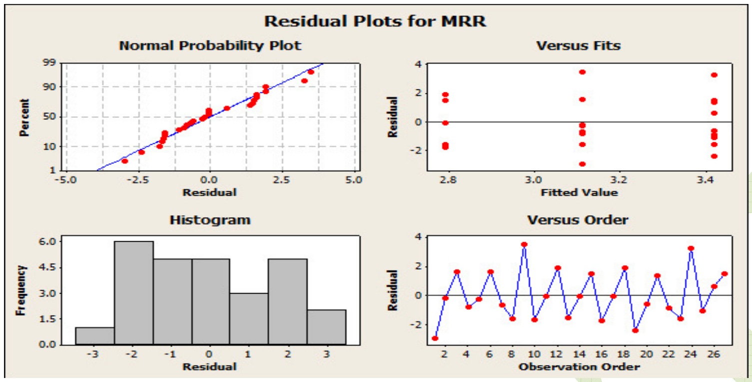



Fig.8 Residual plots for material removal rate versus feed, depth of cut

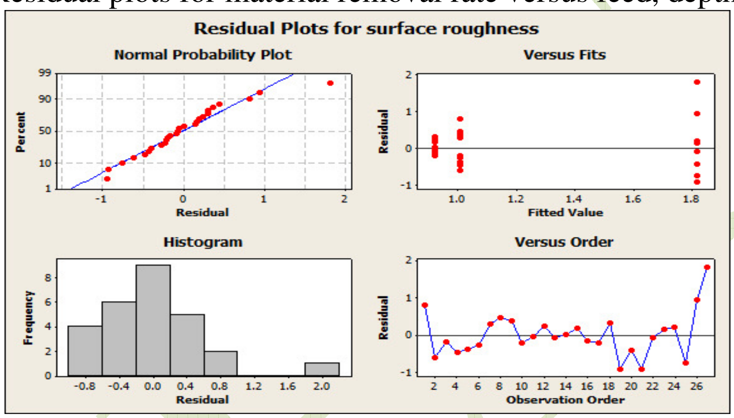



Fig .9Residualplots for surface roughness versus feed, depth of cut

***Conclusions***

This paper presents the optimization of cutting process parameters are cutting speed, feed and depth of cut during the Aluminum 6253 material using the application of ANOVA and ANN analysis. The conclusions drawn from this work are as follows:

The optimum process parameters in the Aluminum 6253 material are:

- Speed of 1500 rpm, feed rate at 70 mm/min and depth of cut at0.8mmfor material removal rate whereas for surface roughness, speed at 1500 rpm, feed rate of 70 mm/min and depth of cut at 0.8 mm are found tobe optimum.
- Speed at 1500 rpm, feed rate of 70 mm/min and depth of cut at 0.8mmfor surface roughness is the optimum parameters.

The ANOVA and ANN results reveal that feed rate and depth of cut are the most significant influencing on the material removal rate and surface finish.

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