NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 3 MARCH2015

Prediction of output Responses in Milling of Casted Aluminum by using ANN

A. Bhargav,
Asst. Professor, Department of ME, S V College of Engineering , Tirupati

N. Rajesh,
Asst. Professor, Department of ME, S V College of Engineering , Tirupati

Dr. CNV Sridhar
Professor, Dept. of ME, AITS, Rajampet.

Abstract
The important goal in the modern industries is to manufacture the products with lower cost and with high quality in short span of time. There are two main practical problems that engineers face in a manufacturing process. The first is to determine the values of process parameters that will yield the desired product quality (meet technical specifications) and the second is to maximize manufacturing system performance using the available resources. The increase of customer needs for quality products (more precise tolerances and better product surface roughness) have driven the metal cutting process. The main objective of this project work is to study the effect of surface roughness and Material Removal Rate in a machining of cast aluminum on CNC milling machine with High Speed Steel cutting tool. The feasibility of implementation of design of experiments (DOE), and Artificial Neural network in milling process is analyzed.

Keywords : Taguchi Analysis, DOE, Milling, ANN

Introduction
Machining is the process of removing the unwanted material from the work piece in the form of chips. If the work piece is a metal, the process is often called as metal cutting process chip forming processes. Metal cutting is a machining process by which a work piece is given as follows

- A desired shape
- A desired size
- A desired surface finish

To achieve one or all of these, the excess (undesired) material is removed (from the work piece) in the form of chips with the help of some properly shaped and sized tools. Metal cutting processes are performed on metal cutting machines, more commonly termed as Machine Tools by means of various types of cutting tools.

The increase of customer needs for quality products (more precise tolerances and better product surface roughness) have driven the metal cutting process. In the global antagonism, manufacturing organizations are working in the direction of improving the product quality and performance of the product with lower cost in short span of time, but practices aimed at lowering the costs don’t usually improve quality.

There is hierarchical relationship between cost and quality. The intense international competition has focused the attention of the manufacturers on automation as means to increase productivity and improve quality. To realize full automation in machining, computer numerically controlled (CNC) machine tools have been implemented during the past decades. CNC machine tools require less operator input, provide greater improvements in productivity and increase the quality of the machined part.

Among several CNC industrial machining processes, milling is a fundamental machining operation. End milling is the most common metal removal operation encountered. It is widely used in a variety of manufacturing industries including the aerospace and automotive sectors, where quality is an important factor in the production of slots, pockets, precision molds and dies etc.,.

The surface roughness plays an imperative role in the manufacturing industry. The quality of surface affects functional requirements and plays a very important role in the performance of the milling as a good quality of milled surface significantly improves fatigue strength, corrosion resistance or creep life. Surface roughness also affects the several functional attributes of parts such as contact causing surface friction, wearing, light reflection, heat transmission and ability of distributing and holding lubricant coating or resisting fatigue. Therefore the desired finish surface is usually specified and the appropriate processes are selected to reach the required quality.

In this work, the design of experiments techniques such as orthogonal arrays in Taguchi design, ANOVA and Artificial Neural Network has been implemented to develop model and analysis for a better product quality.

Literature Review

M.Asad, F.Girardin, T.Mabrouki and J.F. Rigal [1] - study on dry cutting of an aluminium alloy (A2024-T351) using a numerical and experimental approach. For experimental validation, series of test are carried out concerning geometrical analysis of the chip by using high speed camera and high frequency sampling measurement of the cutting force signal are realized. For the numerical approach, the material failure model exploited consider both damage evolution and energy coupling and the result is compared to experimental ones so an analysis of damage distributions is presented.

Abou-El-Hossein et al. [2] predicted the cutting forces in an end milling operation of modified AISI tool steel using the response surface methodology (RSM) and Minitab software.

Shashidhar Madival [3]- performs an analysis of surface roughness in milling composites using neural networks. This project studied the effect of speed and feed on surface roughness and also the optimization of these parameters. Analysis of the experimental data clearly signifies that surface finish deteriorates with increase in feed rate at a given cutting speed. Other factors, such as drill geometry, work piece properties and machining conditions definitely have influence on the quality, but no experimental investigation was done.

Mohammad Reza Soleymani Yazdi and Saeed Zare Chavoshi [4] studied the effect of cutting parameters and cutting forces on rough and finish surface operation and material removal rate (MRR) of AL6061 in CNC face milling operation. The objective was to develop the multiple regression analysis and artificial neural network models for predicting the surface roughness and material removal rate. According to them, in rough operation, the feed rate and depth of cut are the most significant effect parameters on R_a and MRR and increases with the increase of the cutting forces.

DOE and ANN

DOE

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between factors affecting a process and the output of that process. Conducting and analyzing controlled tests to evaluate the factors that control the value of a parameter or group of parameters."Design of Experiments" (DOE) refers to experimental methods used to quantify indeterminate measurements of factors and interactions between factors statistically through observance of forced changes made methodically as directed by mathematically systematic tables.

Design of Experiment Techniques

1. Factorial Design.
2. Response Surface methodology.
3.Mixture Design.
4. Taguchi Design.

Among those we had selected Taguchi Design for optimizing surface finish and cutting forces in face milling Operation.

1 Taguchi method

Competitive crisis in manufacturing during the 1970's and 1980's that gave rise to the modern quality movement, leading to the introduction of Taguchi methods to the U.S. in the 1980's. Taguchi's method is a system of design engineering to increase quality. Taguchi methods refer to a collection of principles which make up the framework of a continually evolving approach to quality. Taguchi Methods of Quality Engineering design is built around three integral elements, the loss function, signal-to-noise ratio, and orthogonal arrays, which are each closely related to the definition of quality.

2 Taguchi approach for parameter design

The objective of the robust design is to find the controllable process parameter settings for which noise or variation has a minimal effect on the product's or process's functional characteristics. It is to be noted that the aim is not to find the parameter settings for the uncontrollable noise variables, but the controllable design variables. To attain this objective, the control parameters, also known as inner array variables, are systematically varied as stipulated by the inner orthogonal array. For each experiment of the inner array, a series of new experiments are conducted by varying the level settings of the uncontrollable noise variables. The level combinations of noise variables are done using the outer orthogonal array. The influence of noise on the performance characteristics can be found using the ratio, where S is the standard deviation of the performance parameters for each inner array experiment and N is the total number of experiment in the outer orthogonal array. This ratio indicates the functional variation due to noise. Using this result, it is possible to predict which control parameter settings will make the process insensitive to noise.

Taguchi method focuses on Robust Design through use of

- Orthogonal arrays.
- Signal-to-Noise ratio.

Orthogonal array

In order to reduce the total number of experiments “Sir Ronald Fisher” developed solution:” orthogonal arrays”. The orthogonal array can be thought of as a distillation mechanism through which the engineers experiment passes (Ealey, 1998). The array allows the engineer to vary multiple variables at one time and obtain the effects which that set of variables has an average and the dispersion. Taguchi method can be calculated based on the degrees of freedom approach.

$$N_{TAGUCHI} = 1 + \sum_{i=1}^{NV} (L_i - 1) \quad \text{---------- (3.1)}$$

Taguchi employs design experiments using specially constructed table, known as "Orthogonal Arrays (OA)" to treat the design process, such that the quality is build into the product during the product design stage.

Signal-to-Noise ratio

The signal-to-noise concept is closely related to the robustness of a product design. A robust design or product delivers strong ‘signal’. It performs its expected function and can cope with variations (“noise”), both internal and external. In signal-to-noise ratio, signal represents the desirable value and noise represents the undesirable value. There are three Signal-to-Noise ratios of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic.

They are

- Smaller-The-Better
- Larger-The-Better

The Signal-To-Noise ratio for the Smaller-The-Better is:

S/N = -10 *log (mean square of the response)

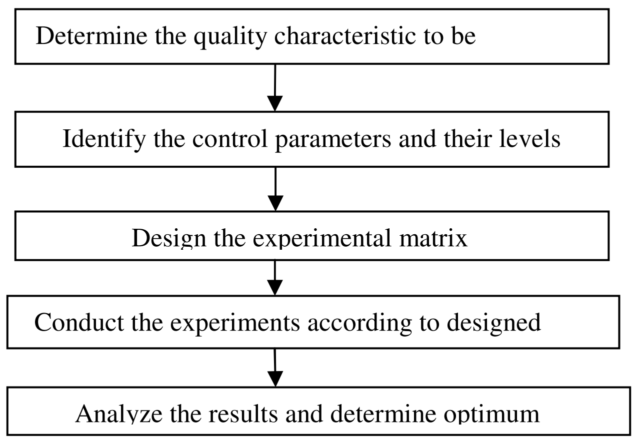
The Signal-To-Noise ratio for the bigger-the-better is:

S/N = -10*log (mean square of the inverse of the response)

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

3 Steps in 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**.**



4. 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.

NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 3 MARCH2015

Artificial Neural Networks (ANN):

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons.

Neural network simulations appear to be a recent development. However, this field was established before the advent of computers, and has survived at least one major setback and several eras.

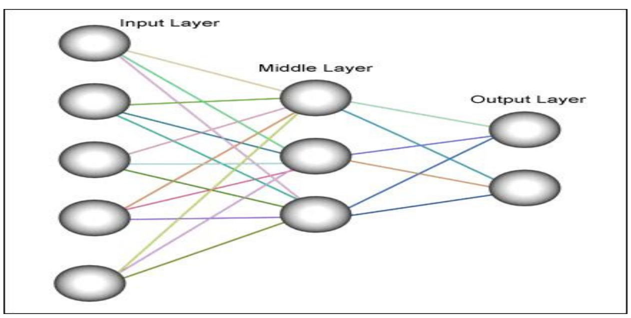


Fig. Configuration of Neural Network

DATA COLLECTION

The experiments are planned using Taguchi’s orthogonal array in the design of experiments (DOE), which helps in reducing the number of experiments. The experiments were conducted according to orthogonal array on CNC face milling machine using coated carbide cutting tool. The four cutting parameters selected for the present work is Diameter (D, mm), cutting speed (V, m/min), feed rate (f, mm/min), and depth of cut (d, mm). Since the considered factors are multi-level variables and their outcome effects are not linearly related, it has been decided to use three level tests for cutting speed, feed rate, depth of cut, and Diameter. The tool holder used for milling operation was Kennametal tool holder BT40ER40080M.

Fig. CNC milling machine XLMILL

The work piece used for the present investigation is Cast Aluminum of flat work pieces of 100mm*100mm*10mm and the density of the material in metric units. The machining parameters used and their levels chosen are given in Table 4.1

Table 4.1 Machining Parameters and their Levels

Control parameters	Units	Symbol	Levels		
			Level 1	Level 2	Level 3
Diameter	Mm	D	5	8	10
Cutting speed	Rpm	N	1000	1500	2000
Feed	mm/min	F	30	40	50
depth of cut	Mm	D	0.5	0.6	0.7

Taguchi's orthogonal array of L_9 ($\mathbf{3^4}$) is most suitable for this experiment. Because, cutting speed, cutting feed, depth of cut and Diameter with Three levels each and then 3×3×3×3=81 runs were required in the experiments for four independent variables. But using Taguchi's orthogonal array the number of experiments reduced to 9 experiments from 81 experiments. This needs 9 runs (experiments) and has 8 degrees of freedom's (DOFs). The L_9 orthogonal array is presented in Table- 4.2

Table-4.2: L9 (3^4) orthogonal array

L9 (3^4)				
S.NO	**Diameter**	**Feed**	**Cutting Speed**	**Depth of cut**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table-4.3: Actual Setting Values for the Coded Values:

S.NO	Diameter (mm)	Feed rate (mm/min)	Cutting Speed (rpm)	Depth of cut (mm)
1	5	30	1000	0.5
2	5	40	1500	0.7
3	5	50	2000	0.6
4	8	30	1500	0.7
5	8	40	2000	0.5
6	8	50	1000	0.6
7	10	30	2000	0.6
8	10	40	1000	0.7
9	10	50	1500	0.5

The surface roughness was measured by using stylus type instrument i.e., Talysurf Surface Roughness meter.

Fig. Talysurf meter

4 Experimental procedure:

i) The parameters which influence the milling process and their levels are listed based on previous works (table 4.4).

ii) Milling operation is performed on Cast Aluminum material according to Taguchi design using the CNC Milling machine.

iii) The surface finish values of work are measured using Talysurf meter (table 4.4).

The experimental results are presented in Table- 4.4.

Table 4.4 : Experimental results for R_a and MRR.

S. NO	Diameter (mm)	Feed rate (mm/min)	Cutting Speed (rpm)	Depth of cut (mm)	R_a (µm)	MRR (mm^3/min)
1	5	30	1000	0.5	1.656667	75.97403
2	5	40	1500	0.7	3.426667	92.98365
3	5	50	2000	0.6	2.26	100.9781
4	8	30	1500	0.7	3.643333	103.0534
5	8	40	2000	0.5	2.476667	100.0741
6	8	50	1000	0.6	4.36	147.2727
7	10	30	2000	0.6	1.31	129.4964
8	10	40	1000	0.7	0.803333	200.6369
9	10	50	1500	0.5	2.36	181.4516

DEVELOPMENT OF ANN AND PREDICTION OF OUTPUT PARAMETERS

Steps in the development of ANN:

i) Generation of input and output data.
ii) Creating Neural Network.
iii) Train the NN with above generated data.
iv) Simulate the network with test data.

i) Generation of input and output data

ii) Creating a network (newff):

The first step in the development of ANN is to create the network object. Using the command "newff" of MATLAB a Neural Network is created with four input neurons and five output neurons. In the present work, four input and five output parameters were identified. Hence the developed network consists of four input neurons and five output neurons.

iii) Train the NN with above generated data

Training function **traingd** to be used for training the network created by using **newff** function. The weights and biases are updated in the direction of negative gradient of the multi-dimensional error surface.

Table4.5. Trained data set for predicted output:

Train data						
S. NO	**Diameter (mm)**	**Feed rate (mm/min)**	**Cutting Speed (rpm)**	**Depth of cut (mm)**	**R_a (μm)**	**MRR (mm^3/min)**
1	5	30	1000	0.5	1.656667	75.97403
2	5	40	1500	0.7	3.426667	92.98365
3	5	50	2000	0.6	2.26	100.9781
4	8	30	1500	0.7	3.643333	103.0534
5	8	40	2000	0.5	2.476667	100.0741
6	8	50	1000	0.6	4.36	147.2727

iv) Simulate the network with test data

Network is simulated with test input which is not included in training data. The output obtained from simulation is compared with experimental output to find out how nicely simulated network is able to model the system for which it is trained. The simulated results are shown in table 4.6

Table4.6 ANN predicted results:

S.NO	Dia (mm)	Feed rate (mm/min)	Cutting Speed (rpm)	Depth of cut (mm)	Experimental Output		Predicted Output	
					R_a (µm)	MRR (mm^3/min)	R_a (µm)	MRR (mm^3/min)
1	10	30	2000	0.6	**1.31**	**129.496**	**1.85**	**110.97**
2	10	40	1000	0.7	**0.80333**	**200.637**	**1.33**	**181.97**
3	10	50	1500	0.5	**2.36**	**181.452**	**2.66**	**163.27**

Table 4.7 : Optimum level factors

Response table for Surface Roughness				
Level	**Dia**	**Feed**	**Speed**	**depth**
1	2.448	2.203	2.273	2.164
2	**3.493**	2.236	**3.143**	**3.032**
3	1.491	**2.993**	2.016	2.236
Response table for MRR				
1	89.98	102.84	**141.29**	119.17
2	116.80	131.23	125.83	123.25
3	**170.53**	**143.23**	110.18	**134.89**

Conclusions

In the present work an Artificial Neural Network (ANN) model has been developed to predict the response (output) parameters surface roughness, material removal rate in the milling of Cast Aluminium. The developed ANN model has been trained and tested with experimental data of milling process. ANN tested results are compared again with experimental results the controllable parameters such as cutting speeds, feed rates, Diameter and Depth of cut which influence the responses in milling of Cast aluminium are identified and analyzed. The optimum combinations of input (controllable) parameters are determined by Taguchi method. The analysis of variance (ANOVA) is also employed to find the contribution of input parameters on output parameters. From analysis surface finish are mostly affected by Feed rate, material removal rate is mostly affected by Depth of cut. The validity of this approach for parameter optimization is well established.

Present work is useful to predict the responses in wide range of input data and it can further be extended for other machining process. This work may also helps in reducing the experimental cost while modeling of complex machining process.

References

[1]. Asad M., Girardin F., Mabrouki T. and Rigal J.F., *" Dry cutting study of an aluminium alloy(A2024-T351): a numerical and experimental approach,"2002*

[2] K.A Abou-El-Hossein, Kadirgama K, Hamdi M, Benyounis KY, *Prediction of cutting force in end-milling operation of modified AISI P20 tool steel. J Mater Process Technol 182 (2007) (1–3): 241–247.*

[3] Shashidhar Madiwal , " *Analysis of surface finish in milling of composite using neural Networks," Wichita State University.,2006*

[4] Mohammad Reza Soleymani Yazdi and Saeed Zare Chavoshi, *Analysis and estimation of state variables in CNC face milling of AL6061, Prod. Eng. Res. Dev el. 4 (2010) 535–543, doi: 10.1007/s11740-010-0232-7.*