OPTIMIZING AND PREDICTING SURFACE ROUGHNESS ON MILLING MACHINE BY USING TAGUCHI &

ANN ON D2 STEEL

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ABSTRACT

Optimization means to find best value of input. For this Taguchi method gives the best output result. ANOVA is the most effecting parameter. This parameter affects the most among all the input parameters. Modeling is done by ANN. It is best network model which gives minimum error between network output and real output. Prediction is done by both methods. Result of both methods is compared. Best method is used which gives the minimum error. Milling process is used here because milling is most commonly used in industries. It can perform many tasks. D2 steel is used here. Various parameter are considered in this are taken from the previous papers. Taguchi and ANN methods are used because these are the most famous and developing methods. Taguchi method is used for optimization. It is done by studying the mathematical relation between input and output. Signal to noise ratio is basically considered in the optimization process. Signal should be large and noise should be less. ANN method is used for prediction. It shows that for any value of input data we can easily predict the output with minimum error.

Keywords: Milling machining, D2 steel, surface roughness, Taguchi, ANOVA, ANN etc.

I.   INTRODUCTION

Recent functionality requirements have led to development of components with varying free-form features. Sculptured surfaces have free-form features with both convex and concave regions that can be geometrically fitted by ball-end cutter. The parts with free from geometric features are generally machined using ball-end cutters, which are used to manufacture parts in die/mould, aerospace, biomedical and automotive industries where both part quality and manufacturing time are metrics for high productivity. The ultimate goal of virtual machining process research is to identify process related issues and solve them before the costly physical trials in the shop. Modeling the process mathematically is necessary to achieve that goal in a Reasonable amount of time and the first step of process modeling is to model the mechanics of the operation that leads to the prediction of the cutting forces experienced by the cutting tool and the work-piece.

II. LITERATURE REVIEW

R. Peres et.al. (1999) proposed that process optimization is a very important subject to several industrial sectors in confronting the growth on markets competition. However, due to the complexity of some processes, their optimization is not an easy task; therefore, to accomplish this objective, intelligent techniques should be used. We are working on end-milling process optimization through combining analytic and fuzzy techniques.

J. F. Briceno et.al. (2002) proposed that two supervised neural networks are used to estimate the forces developed during milling. These two Artificial Neural Networks (ANNs) are compared based on a cost function that relates the size of the training data to the accuracy of the model.

H. E. Mounayri et.al. (2005) proposed an integrated product development system for optimized CNC ball end milling is presented. First, the developed model is extended from flat end milling to ball end milling. Second, the optimization is extended from 2D (speed and feed) to 3 (1/2) D (speed, feed, radial and axial depths of cut).

K.Kadirgama et.al. (2008) is concerned with optimization of the surface roughness when milling Mould Aluminum alloys (AA6061-T6) with carbide coated inserts. Optimization of milling is very useful to reduce cost and time for machining mould. The approach is based on Response Surface Method (RSM) and Radian Basis Function Network (RBFN).

S.Brevern et.al. (2009) proposed that the world of manufacturing has shifted its level to the era of space age machining. The purpose of this investigation is to develop Fuzzy based Graphical User Interface (GUI) for modeling of laser machining conditions.

M.S. Yazdi et.al. (2010) studied that the selection of optimal machining parameters (i.e., spindle speed, depth of cut and feed rate) for face milling operations was investigated in order to minimize the surface roughness and to maximize the material removal rate. Effects of selected parameters on process variables (i.e., surface roughness and material removal rate) were investigated using Response Surface Methodology (RSM) and artificial neural networks.

S.Moshat et.al. (2010) proposed that End milling is the most important milling operation, widely used in most of the manufacturing industries due to its capability of producing complex geometric surfaces with reasonable accuracy and surface finish. However, with the inventions of CNC milling machine, the flexibility has been adopted along with versatility in end milling process.

B. S.Reddy et.al. (2011) proposed that Pre-hardened steel (P20) is a widely used material in the production of moulds/dies due to less wear resistance and used for large components. In this study, minimization of surface roughness has been investigated by integrating design of experiment method, Response surface methodology (RSM) and genetic algorithm.

A. K.Gupta et.al. (2011) proposed that the optimum combination of machining parameters has been analyzed for maximizing the tool life with the constraints of material removal rate (MRR) and surface finish. To optimize these parameters the correct relationship of process parameters with tool life has been found. Mathematical relations have been developed for predicting the objectives with different combinations of parameters under the specified constraints. As there is a variety of milling processes, cutting tool geometries, cutting tool material, work piece material and machine tool conditions, hence difficult to develop a single robust analytical relation for tool life.

P.Maurya et.al. (2012) studied on CNC end milling, influence of various machining parameters like, tool feed (mm/min),tool speed (rpm), tool diameter (mm) and depth of cut (mm). In the present study, experiments are conducted on AL 6351 –T6material with three levels and four factors to optimize process parameter and surface roughness

S. Hossain et. al. (2012) proposed that Surface roughness is an index which determines the quality of machined products and is influenced by the cutting parameters. In this study the average surface

roughness (Ra) value for Aluminum after ball end milling operation has been measured. 84 experiments have been conducted varying cutter axis inclination angle (ϕ degree), spindle speed (S rpm), feed rate (mm/min), radial depth of cut (feed f mm), and axial depth of cut (t mm) in order to find Ra. This data has been divided into two sets on a random basis; 68 training data set and 16 testing data set.

A.Behera et. al. (2012) proposed that Plasma spraying technique has become a subject of intense research in many industrial structural/functional applications because its peculiarity surface properties. This investigation explains about plasma sprayed copper surface property. Here industrial waste and low grade ore (i.e. Flay-ash+ quartz+ limonite), used as deposit material which is to be coated on copper substrates. In many applications, it is found that for structural modification, surface roughness & porosity parameters are very important. To decrease both surface roughness and coating porosity by optimizing other necessary properties, different soft computing methods like Artificial Neural Network (ANN) and Least Square support vector machine techniques used.

III. EXPERIMENTAL DETAILS

End Milling

Among different types of milling processes, end milling is one of the most vital and common metal cutting operations used for machining parts because of its capability to remove materials at faster rate with a reasonably good surface quality. Also, it is capable of producing a variety of configurations using milling cutter. In end milling, the cutter, called end mill, has a diameter less than the work piece width. The end mill has helical cutting edges carried over onto the cylindrical cutter surface. End mills with flat ends (so called squire-end mills) are used to produce pockets, closed or end key slots, etc.

In end milling an end mill makes either peripheral or slot cuts, determined by the step-over distance, across the work piece in order to machine a specified feature such as a profile, slot, pocket, or even a

complex surface contour. The depth of the feature may be machined in a single pass or may be reached by machining at a smaller axial depth of cut and making multiple passes.

Material Used

In this work hardened AISI D2 steel (hardness 50-70 HRC) will be used as the work piece material and Tungsten carbide preferably coated will be used as the tool material. Because increasing tool life is main concern of hard machining to decrease the cost of the machining process. A particular amount of maximum flank wear say 0.2 to 0.3 µm can be used as the tool life failure criterion. Flank wear can be measured using toolmaker's microscope. The chemical composition of AISI D2 tool steel is given in below Table 3.1.

Table 3.1 Chemical Composition of Steel

Carbon	Silicon	Manganese	Chromium	Molybdenum	Vanadium
1.55 %	0.30 %	0.35 %	12 %	0.75 %	0.90%

AISI D2 is recommended for tools requiring very high wear resistance, combined with moderate toughness (shock-resistance). AISI D2 can be supplied in various finishes, including the hot-rolled, pre-machined and fine machined condition forming Dies, Punches, Forming Rolls, Knives, Slitters, Shear blades.

Machine Used

Machining was carried out in CNC machine at CTR, Ludhiana.

Figure 1. CNC Milling Machine

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Table 3.2 Specification of CNC Milling Machine

Table Size	915 * 356 mm
Table Load	341 KG
Power	3 phase, 60 Hz
Control	GE FANUC 211
X Axis Travel	560 mm
Y Axis Travel	406 mm
Z Axis Travel	508 mm
Spindle Speed	100 RPM Direct Drive
Spindle Diameter	65 mm
Spindle Taper	ISO-40
Tool Taper	BT-40
Magazine Capacity	22 Tools
Maximum Wt. of Tool Holder	50 KG
Maximum Tool Length	254

Table 3.3 Levels of Input Control Parameters

Factors	*Levels*	*Factor Level values*
Speed (rpm)	3	500,750,1000
Depth of Cut (mm)	3	0.75,0.50,0.25
Feed (mm/min)	3	750,1000,1250

The optimum condition is identified by studying the main effects of each of the parameters. The main effects indicate the general trend of influence of each parameter. The knowledge of contribution of individual parameters is a key in deciding the nature of control to be established on a production process. Orthogonal Array is a statistical method of defining parameters that converts test areas into factors and levels. Test design using orthogonal array creates an efficient and concise test suite with fewer test cases without compromising test coverage. An orthogonal array is a "table" (array) whose entries come from a fixed finite set of symbols (typically, {1,2,..., n}), arranged in such a way that there is an integer t so that for every selection of t columns of the table, all ordered t-tuples of the symbols, formed by taking the entries in each row restricted to these columns, appear the same number of times. The number t is called the strength of the orthogonal array. The Table 3.4 shows the design matrix used in this work.

Table 3.4 Orthogonal Array L9

Sample No.	Spindle Speed (rpm)	Feed Rate (mm/min.)	Depth Of Cut (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

IV. EXPERIMENTAL PROCEDURES

- Checking and preparing the Centre Lathe ready for performing the machining operation.

- Firstly, the work-piece was cut according to above mentioned dimension i.e. 100*100*25 mm by cutter of diameter 32 mm.

- For developing models on the basis of experimental data three main machining parameters are considered to predict surface roughness of D2 material using carbide tool. Among the range of spindle speed, feed, and depth of cut available possible in the machine the following three levels are considered as shown in Table 3.3.

- The machining was carried out on end milling machine, the material work piece is clamped on vice mounted on the table of the machine. The machining process and work tool motion of the end milling process respectively.

- The machining is carried out by selecting proper spindle speed and feed rate during each experimentation. Experiment was carried out by varying the depth of cut.

Taguchi's designs aimed to allow greater understanding of variation than did many of the traditional designs. Taguchi contended that conventional sampling is inadequate here as there is no way of obtaining a random sample of future conditions. Taguchi suggests a three-stage process:

- System design,

- Parameter design,

- Tolerance design.

System design is the conceptualization and synthesis of a product or process to be used. In parameter design the system variables are experimentally analyzed to determine how the product or process reacts to uncontrollable "noise" in the system; parameter design is the main thrust of Taguchi's

approach. The final step in Taguchi's robust design approach is tolerance design; tolerance design occurs when the tolerances for the products or process are established to minimize the sum of the manufacturing and lifetime costs of the product or process.

Taguchi proposed extending each experiment with an "outer array" or orthogonal array should simulate the random environment in which the experiment would function. Here we use L9 orthogonal array with 3 levels. In this work, L9 Orthogonal Array design matrix is used to set the control parameters to evaluate the process performance. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab. Orthogonal Array design of experiment has been found suitable in the present work.

V. RESULTS AND DISCUSSION

End milling is one of the most fundamental and commonly encountered chip removal operations occurring in a real manufacturing environment. In this machining process, the surface finish is a key factor in evaluating and determining the quality of a part. In practice, a desired surface roughness value is usually designated, and the appropriate cutting parameters are selected to achieve the desired quality of a specified part. The single point incremental forming (SPIF) process is performed on three-axis CNC machine.

Table 5.1 Measured Surface Roughness

Pieces	Speed (rpm)	Depth of Cut (mm)	Feed (mm/min)	Surface Roughness (μm)
1	500	750	0.75	0.73
2	500	1000	0.50	0.77
3	500	1250	0.25	0.82
4	750	750	0.50	0.72
5	750	1000	0.25	0.49
6	750	1250	0.75	0.63
7	1000	750	0.25	0.42
8	1000	1000	0.75	0.72
9	1000	1250	0.50	0.55

Table 5.2 Measured Roughness Parameters

Pieces	R_a (µm)	R_t (µm)	R_z (µm)	R_c (µm)
1	0.73	3.94	2.97	1,91
2	0.77	4.22	3,34	2.45
3	0.82	4.46	3.62	2.88
4	0.72	3.87	2.94	1.87
5	0.49	2.14	1.82	1.21
6	0.63	3.41	2.69	1.64
7	0.42	2.02	1.71	1.16
8	0.72	3.89	2.95	1.88
9	0.55	2.87	1.98	1.34

The main objective of the thesis is to optimize the milling parameters (spindle speed, feed rate, depth of cut and cutting tool grade) to achieve low value of the surface roughness. The experimental data for the surface roughness values is shown in Table 5.1.

6.1.2 Optimization by Taguchi Method

Since 1960, Taguchi methods have been used for improving the quality of Japanese products with great success. During the 1980's, many companies finally realized that the old methods for ensuring quality were not competitive with the Japanese methods. Performance characteristics are first converted into the S/N ratio using the Taguchi method. Using S/N quantity, optimal performance and minimal variance can be designed. The SR value is calculated for each trial from the basic data collected . The signal to-noise ratios of each experimental run are calculated based on the following equation, which are listed in corresponding tables with the data.

$$SNR = -10 log \frac{1}{n} \sum y^2$$
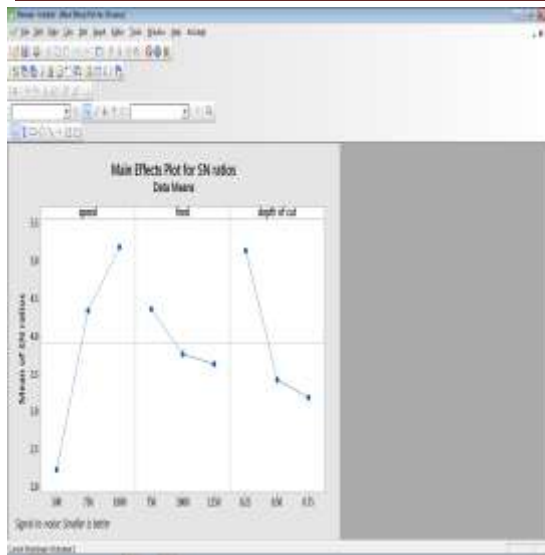
Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
speed	2	13.8738	44.60%	13.8738	6.9369	1.46	0.407
feed	2	0.9118	2.93%	0.9118	0.4559	0.10	0.913
depth of cut	2	6.7995	21.86%	6.7995	3.3997	0.71	0.583
Error	2	9.5201	30.61%	9.5201	4.7600		
Total	8	31.1052	100.00%				

Figure 2-S/N ratio   Table 5.3 ANOVA

Table 5.4 Comparison of Taguchi and ANN

Output Comparison of Taguchi Method and ANN Technique

Pieces	SR	PSR (Taguchi)	Error (Taguchi)	Output (ANN)	Error (ANN)
1	0.73	0.79	0.06	0.73	0
2	0.77	0.81	0.04	0.77	0
3	0.82	0.71	-0.11	0.75	-0.07
4	0.72	0.61	-0.11	0.62	-0.1
5	0.49	0.55	0.06	0.49	0
6	0.63	0.67	0.04	0.63	0
7	0.42	0.46	0.04	0.42	0
8	0.72	0.61	-0.11	0.72	0
9	0.55	0.61	0.06	0.55	0

VI. CONCLUSION

1. The higher the cutting speed, the lower is the surface roughness.

2. The experimental results show that average surface roughness is low at lower depth of cut.

3. For achieving good surface finish on the D2 work piece, higher cutting speed, lower feed and lower depth of cut are preferred. The optimal parametric combination for AISI D2 Steel is speed3-feed1- depth of cut1.

4. ANOVA shows that the cutting speed is the most influencing parameter for surface roughness.

5. Mean Absolute Percentage Error is calculated in Taguchi method is 10.77% and Mean Absolute Percentage is Calculated in MATLAB is 2.90% so ANN technique gives us better results than Taguchi method .Error is minimized by ANN technique.

6. Best Model achieved in ANN is with feed forwarded back propagation neural network with Levenberg-Marquardt training function with three layers.

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