# Reducing the Surface Roughness of Pneumatic Cylinder Piston Rod in Turning Process Using Genetic Algorithm

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***Abstract*—Surface roughness (R) is an indication of product quality. Inferior surface finish is observed in piston rod after turned using CNC lathe. This results in poor product quality. The optimum set of cutting parameters to minimize the surface roughness in turning operation, using Genetic Algorithm (GA). The control parameters for the study included speed (N), feed (f), depth of cut (d), and tool nose radius (r). A total of nine experiments were conducted using $L_9$ ($3^4$) orthogonal array and the optimal combination of control factor levels were determined for the minimum surface roughness based on signal-to-noise ratio. Using MINITAB software, the mathematical model of the process was formulated for the surface roughness. Taking the model as objective function further optimization has been carried out using Genetic algorithm (GA). Using GA-tool in the MATLAB software, the objective function has been minimized and corresponding combination of cutting parameters found.**

***Keywords- Surface roughness, Cutting parameter, Taguchi method, Orthogonal array, Regression analysis & Genetic algorithm.***

## I. INTRODUCTION

Globalization of market creates a challenging environment in products marketing. High competition induces the manufacturing to produce better quality products within short period of time as well as at low cost. Precision products could be produces with the machines at optimum working conditions. Optimum machining parameters are of great concern in manufacturing environments, where economy of machining operation plays a key role in competitiveness in the market. A typical turning operation produces parts which have critical features requiring a specified surface roughness. Hence the surface roughness is an important quality for products. In this paper, find the optimum setting of cutting parameters to minimize the surface roughness in turning operation, using Genetic algorithm. The study included speed, feed, depth of cut, and tool nose radius.

Process modeling and optimization are two important issues in manufacturing. In order to get the exact model that relates the surface roughness and the machining parameters, a large number of experiments needed. This may not be possible due to the cost of the model and machining time required. Hence an orthogonal design with least number of experiments is recommended. These experiments have been multiplexed into more number of parameter combination sets based on Taguchi’s orthogonal array. Through the application of MINITAB, based on these a mathematical model is developed using regression analysis. Using the model as an objective function in the Genetic algorithm, the optimum cutting parameter combination has found.

## II. LITERATURE SURVEY

**[1]** Developed Taguchi parameter design which provides a systematic procedure that can effectively and efficiently identify the optimum surface finish in the process of CNC turning operation and also explained about Taguchi advantages compared to Design of Experiment. [2] Reviewed the control parameters of CNC turning operation and proposed depth of cut is a significant factor for surface roughness in turning operation. [3] Presented a work base on hard turning operation and proposed depth of cut is a significant factor for surface roughness in turning operation. [4] Explained about Multi-objective Genetic Algorithm and presented the application of Genetic Algorithm. [5] Presented a work based on Real coded Genetic Algorithm and explained its applications in optimization problems. [6] The work in turning operation, presented the relation between control factors and surface roughness, which reviewed the surface roughness, is minimum when the control factors cutting speed and feed rate are higher. [7] The work included tool nose radius, cutting speed, depth of cut, feed and thrust force, which gave the information that the higher speed, smaller depth of cut and larger tool-tip radius help to decrease the surface roughness.

## III. METHODOLOGY

A products quality cost can be divided into two main parts, namely before sale and after sale to customer. The cost incurred before sale are the manufacturing costs and the costs incurred after sale are those due to quality loss. Taguchi asserts that the product and process design have a much greater impact on product quality than manufacturing and inspection, i.e. Quality should be built into the product and applied to it. Quality is best achieved by minimizing the deviation from the target.

There are three stages in Taguchi methodology,

- System design
- Parameter design
- Tolerance design

In system design, development of prototype design is done to meet customer requirements. This stage deals with determination of materials, parts, components, assembly system, manufacturing technology etc in parameter design, the levels of design variables (control factors) are determined to minimize the effect of uncontrolled factors on the products quality. Tolerance design applied if the reduction in quality variation achieved by parameter design is insufficient. In order to have a clear view of Taguchi technique, there needs a basic knowledge about the types of quality characteristics and types of factors involved in the technique.

### A. *Steps in Taguchi technique*

The steps in Taguchi technique are shown figure 1

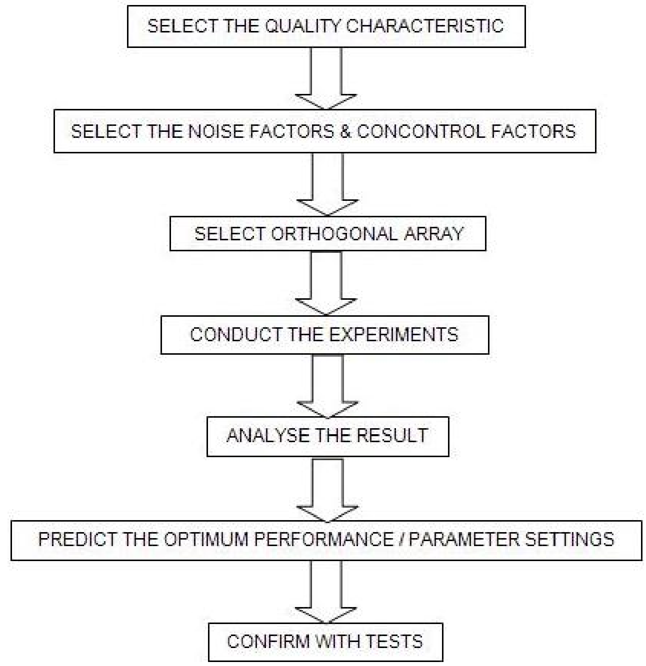


Figure: 1 Steps in Taguchi parameter design

### B. *Selecting an orthogonal array*

Orthogonal array allow researchers to study many design parameters simultaneously and can be used to estimate the effect of each factor independently of the other factors. Thus the information about the design parameters can be obtained with minimum time and resources. In order to select the orthogonal array, the number of degrees of freedom for the factors and levels must be equal or greater than the number of degrees of freedom for the orthogonal array.

Taguchi has tabulated 18 orthogonal arrays which are called standard orthogonal arrays.

i.e. $V_O \geq V_L$

where

$V_O$ - Number of degrees of freedom for the orthogonal array.

$V_L$ - Number of degrees of freedom for the factors and levels.

Number of parameters taken in this work as 4
Number of levels in each parameter taken as 3

Degrees of freedom of parameter levels
$V_L$ = Number of parameters X (degrees of freedom of parameter levels)
= 4 X (3-1)
= 8
Degrees of freedom of orthogonal array
$V_O$ = Number of experiments – 1
= 9-1
= 8

In this work $V_O = V_L$ Hence, $L_9$ ($3^4$) orthogonal array was selected.

### *C. Control factors and levels*

Control factors whose values are controlled by designer. Levels are the value that assigned to a factor, which may be control, noise, signal or scaling factor. Parameters considered in this study are nose radius, depth of cut, spindle speed and feed rate. Levels of machining parameters are shown in table 1.

Table: 1 CONTROL FACTORS AND LEVELS

| Control factors | Factor levels | | |
|---|---|---|---|
| | Level 1 | Level 2 | Level 3 |
| Tool nose radius 'r' mm) | 0.4 | 0.8 | 1.2 |
| Depth of cut 'a' (mm) | 0.5 | 1.0 | 1.5 |
| Spindle speed 'N' (rpm) | 1000 | 1750 | 2500 |
| Feed rate 'f' (mm/rev) | 0.1 | 0.2 | 0.3 |

The S/N ratio consolidates several repetition (at least two data points are required) n to one value that reflects the amount of variation present. These are smaller the better (SB), nominal the best (NB) and larger the better (LB). In this work smaller the better quality characteristic has been chosen, as the performance characteristic is surface roughness,

$$S/N = -10\log \Sigma (\sigma^2 + R^2) \quad (1)$$

Where,

σ - Standard deviation of surface roughness
R – Mean value of surface roughness

The average effects of S/N ratio for each level of process parameters are calculated and form a table as shown in table 2, from the table the optimal cutting parameter levels ware identified.

Table: 2 S/N ratio response table for process parameter

| LEVELS | Nose Radius (A) | Depth of cut (B) | Spindle speed (C) | Feed rate (D) |
|---|---|---|---|---|
| Level 1 | A1 | B1 | C1 | D1 |
| Level 2 | A2 | B2 | C2 | D2 |
| Level 3 | A3 | B3 | C3 | D3 |

In the table 2 the biggest number shows corresponding level was optimum parameter for each control factor

### *D. Genetic Algorithm (GA)*

The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. The steps of the GA are as follows.

**Step - 1:** Choose a coding to represent problem parameters, a selection operator, a crossover operator, and a mutation operator. Choose population size, crossover probability, and mutation probability. Choose a maximum allowable generation and Initialize a random population of strings.

**Step - 2:** Evaluate each string in the population

**Step-3:** If a termination criterion is satisfied, terminate.

**Step - 4:** Perform reproduction on the population.

**Step - 5:** Perform crossover on random pairs of strings.

**Step - 6:** Perform mutation on every string.

**Step - 7:** Evaluate strings in the new population, and go to step-3.

Genetic algorithm begins with initial generation that is computed in the fitness function. If the value of the best fitness is minimum, the process is stopped. Otherwise the new generation is produced through the operators such as reproduction, crossover and mutation. The new generation was computed in the fitness function. This procedure is repeated until the target/minimum value is achieved.

## IV. RESULTS AND DISCUSSION

After selection of orthogonal array, next step is to conduct the experiment. CNC turning machine has been chosen for machining the specimen because the CNC machine is reliable compare to conventional lathe machine for accuracy. The experimental setup was shown in figure 2.

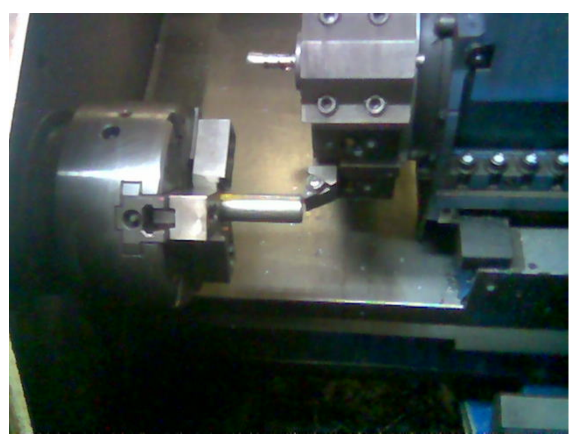

Figure: 2 Work piece in CNC turning machine

The nine experiments were conducted as per the values assigned. Each specimen was machined with its corresponding machining conditions. After complete the experiment, surface roughness values are taken using surface tester instrument. In this work smaller the better quality characteristics has been chosen. Signal to noise ratio values for the trial are shown in table 3.

Table 3 Experimental values and S/N ratios

| Exp. | Nose radius 'r' (mm) | Depth of cut 'd' (mm) | Spindle speed 'N' (rpm) | Feed rate 'f' (mm/rev) | R (μm) | σ | S/N ratio |
|---|---|---|---|---|---|---|---|
| 1 | 0.4 | 0.5 | 1000 | 0.1 | 1.93 | 0.107 | -5.71 |
| 2 | 0.4 | 1.0 | 1750 | 0.2 | 2.62 | 0.017 | -8.37 |
| 3 | 0.4 | 1.5 | 2500 | 0.3 | 5.59 | 0.295 | -14.95 |
| 4 | 0.8 | 0.5 | 1750 | 0.3 | 3.66 | 0.046 | -11.27 |
| 5 | 0.8 | 1.0 | 2500 | 0.1 | 0.83 | 0.182 | 1.62 |
| 6 | 0.8 | 1.5 | 1000 | 0.2 | 2.59 | 0.140 | -8.27 |
| 7 | 1.2 | 0.5 | 2500 | 0.2 | 1.38 | 0.015 | -2.8 |
| 8 | 1.2 | 1.0 | 1000 | 0.3 | 5.41 | 0.612 | -14.66 |
| 9 | 1.2 | 1.5 | 1750 | 0.1 | 2.42 | 0.050 | -7.68 |

The average effects for each level of process parameters are shown in table 4, from the table the optimal cutting parameter levels ware identified.

Table 4 Response of process parameter

| LEVELS | Nose Radius | Depth of cut | Spindle speed | Feed rate |
|---|---|---|---|---|
| Level 1 | -9.68 | **-6.6** | -9.57 | **-3.99** |
| Level 2 | **-6.04** | -7.22 | -9.11 | -6.48 |
| Level 3 | -8.4 | -10.31 | **-5.44** | -13.65 |

In the table 4 the biggest number shows corresponding level was optimum parameter for each control factor. Hence the optimum parameters are

Nose Radius, r = 0.8 mm
Depth of cut, d = 0.5 mm
Spindle speed, N = 2500 rpm
Feed rate, f = 0.1 mm/rev.

## *A. Response curve for surface roughness*

Response curves are graphical representation of change in performance characteristics with the variation in machining parameter level. The curves give a pictorial view of variation of each factor and describe what the effect on the system performance would be when a parameter shifts from one level to another.

Fig 3, Fig 4, Fig 5 & Fig 6 shows that the response graphs for four factors. Level 2 of nose radius, level 3 of depth of cut, level 2 of spindle speed and level 2 of feed rate gives the highest S/N ratio values, which indicates the optimum levels of machining parameters.

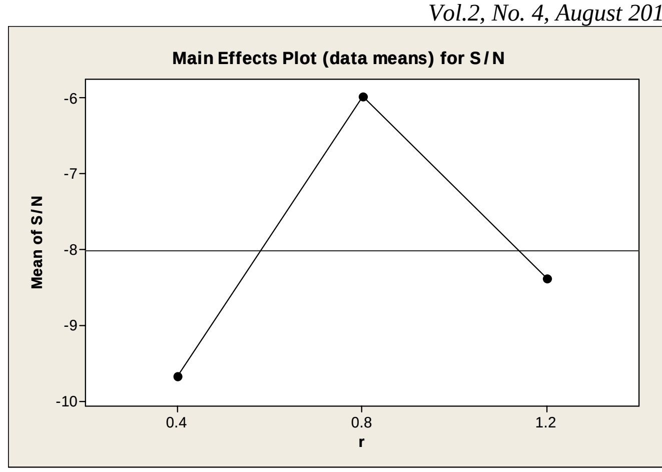


Fig.3 Nose radius versus mean S/N ratio

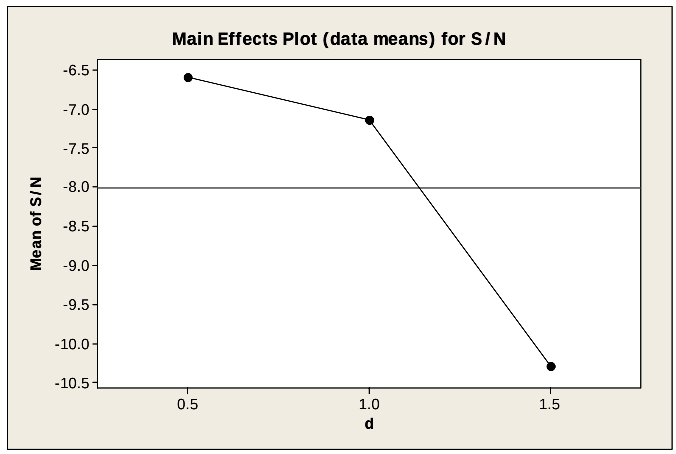


Fig 4 Depth of cut versus mean S/N ratio

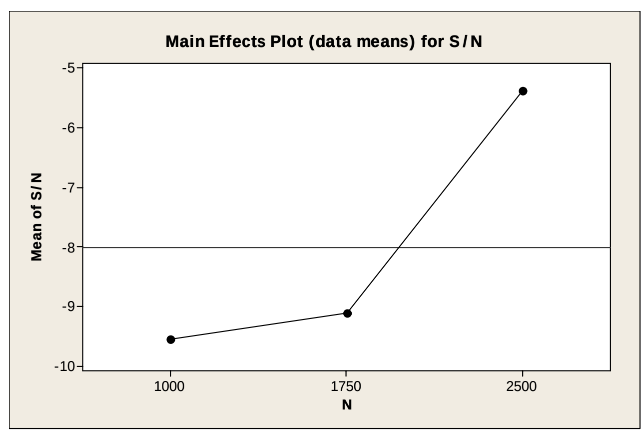


Fig 5 Spindle speed versus mean S/N ratio

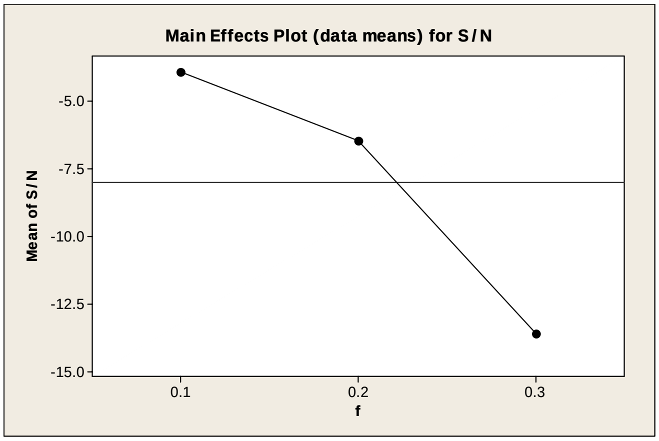


Fig 6 Feed rates versus mean S/N ratio

Confirmation experiment has been conducted at the optimum set of parameter. i.e nose radius 0.8 mm, depth of cut 0.5 mm, spindle speed 2500 rpm, feed rate 0.1 mm/rev and the measured surface roughness is 0.76 µm.

## V. CONCLUSION

- This research work concentrates on minimizing the surface roughness using optimal factors through Taguchi's orthogonal array and genetic algorithm.
- The control factors with three levels and the experiments were conducted in a CNC turning machine.
- A mathematical model was also developed through MINITAB software. Using the model as an objective function the parameters setting was further optimized through Genetic algorithm using MATLAB software. .
- The optimum parameters finally chosen using Taguchi orthogonal array are Nose Radius, r = 0.8 mm, Depth of cut, d = 0.5 mm, Spindle speed, N = 2500 rpm & Feed rate, f = 0.1 mm/rev and the measured surface roughness was 0.76 µm.
- By using Genetic algorithm the optimum parameters was Nose radius, r = 0.8 mm, Depth of cut, d = 0.52 mm, Spindle speed, N = 2450 rpm and feed rate, f = 0.12 mm/rev and the measured surface roughness was 0.49 µm.
- The best result obtained from Genetic algorithm was verified with confirmation test.

## REFERENCES

[1] E.Daniel Kirby, Zhe zhang, Joseph C.Chen, and Jacob Chen., 2006, "Optimizing surface finish in a turning operation using the Taguchi parameter design method", Int. J Adv Manuf Technol., 30,pp. 1021 - 1029

[2] S.Thamizhmanii, S.Saparudin and S.Hasan., 2007,"Analyses of surface roughness by turning process using Taguchi method", J of AMME, 20,pp. 503 - 506

[3] J.Kopac, A.Stoic and M.Lucic., 2006, "Dynamic instability of the hard turning process", J of AMME,17,pp. 373 - 376

[4] S.Thamizhmanii and S.Hasan, 2006, "Analyses of roughness, forces and wear in turning gray cast iron", J of AMME, 17,pp. 401-404

[5] Hong Yan, J.Hua and R.Shivpuri, 2005, "Numerical simulation of finish hard turning for AISI H13 die steel", STAM, 06, pp 540-547

[6] G.A. Ibrahim, C.H. Che Haron and J.A. Ghani, 2009, " The Effect of Dry Machining on Surface Integrity of Titanium Alloy Ti-6Al-4V ELI", Journal of Applied Sciences, 09, pp. 121-127

[7] Raviraj Shetty, R.Pai, V.Kamath and S.S. Rao, 2008, " Study on Surface Roughness Minimization In Turning of Dracs Using Surface Roughness Methodology And Taguchi Under Pressured Steam Jet Approach", ARPN Journal of Engineering and Applied Sciences, 3,No.1, pp. 59-67

[8] N.Belavendram, 2002, " Quality by Design.", Prentice Hall, London.

[9] M. Joseph Davidson, K.Balasubramanian and G.R.N. Tagore, 2008, " Surface roughness prediction of flow-formed AA6061 alloy by Design of Experiments", Journal of Materials Processing Technology, 202, pp 41-46

[10] Tugrul Ozel and Yigit Karpat, 2005, "Predictive modeling of Surface roughness and tool wear in hard turning using regression and neural networks", International Journal of Machine Tools and Manufacture, 45, pp.467-479

[11] Dr. Joseph C. Chen, Mr. Luke H. Huang, Ms. Ashley X. Lan and Mr. Samson Lee, 1999," Analysis of an Effective Sensing Location for an In-process Surface Recognition System in Turning Operations", Journal of Industrial Technology, 15,No.3 , pp.1-6

[12] KHAN M.M.A. and DHAR N.R. 2006, Performance evaluation of minimum quantity lubrication by vegetable oil in terms of cutting force, cutting zone temperature, toolwear, job dimension and surface finish in turning AISI-1060 steel

[13] Hasan G¨O KKAYA, 2005, The Effects of Cutting Tool Coating on the Surface Roughness of AISI 1015 Steel Depending on Cutting Parameters

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