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Optimization of the Parameter in Cylindrical Grinding of Mild Steel Rod (EN19) By Taguchi Method

Swati S Sangale, Dr. A. D. Dongare

PG Scholar, Department of Mechanical Engineering, Sir Visvesvaraya Institute of Technology, Chincholi, Nashik, Savitribai Phule Pune University, India

Associate Professor, Department of Mechanical Engineering, Sir Visvesvaraya Institute of Technology, Chincholi, Nashik, Savitribai Phule Pune University, India

ABSTRACT

The manufacturing process of cylindrical grinding has been established in the mass production of slim, rotationally symmetrical component. Due to the complex set-up, which results from the large sensitivity of this grinding process to a multiplicity of geometrical, kinematical dynamical influence parameters, cylindrical grinding is rarely applied with limited-lot production. The important qualities of this grinding process are the at the same time opinion and machining of the work part on its periphery. Cylindrical grinding is an essential process for final machining of components requires smooth cylindrical and precise tolerances. As made a comparison with other machining processes grinding is high priced of great value operation that should be made use of under most good conditions. Also widely used in industrial areas, grinding remains perhaps the least understood of all machining processes. The proposed work takes the following input process parameters namely Work speed, Depth of cut and Feed. The main objective of this work is to predict the grinding behavior and achieve optimal operating process parameters. Software is used to utilize which integrates these various models to simulate what happens during cylindrical grinding processes. Predictions from this simulation will be further analyzed, calibration with actual data. It involves some variables that is depth of cut, work speed, feed rate, chemical composition of work piece, etc. The main objective in any machining process is to maximize the Metal Removal Rate (MRR) and to minimize the cylindrical roughness. In order to optimize these values Taguchi method, regression analysis and ANOVA is used.

Keywords : Taguchi method, ANOVA, Speed, Feed rate, Depth of cut, Material Remove rate (MRR) and Surface Roughness (Ra).

I. INTRODUCTION

Grinding is a process of material removal and surface area generation process used to condition and finish elements made of metals and other materials. The surface area finish and precision acquired through grinding could be up to ten times much better than with either milling or perhaps turning. Grinding employs a great abrasive product, usually a rotating wheel brought in handled contact with a work surface. The Grinding wheel is composed of abrasive grains held collectively within a binder. These types of| abrasive grains act while cutting tools to eliminating microchips of textile from the work. Because these abrasive grains use and become dull, the added resistance causes inability of the grains or perhaps weakening of their relationship. The dull pieces break away. The requirements intended for efficient grinding include:

- Abrasive elements which will be harder than work.
- Heat-resistant and shock abrasive wheels.
- Abrasives that is friable.

That is usually, most abrasives utilized in market are synthetic. Corundum can be used in three quarters of all of the grinding operations, and is usually primary used to mill ferrous metals. Next is usually silicon carbide, which can be used for grinding softer, large density materials and non- ferrous metals such as substantiate carbide or ceramics. Excellent abrasives, namely cubic boron nitride and diamond, are being used about five percent of grinding. Hard ferrous components are ground with "CBN", while non-ferrous materials and non-metals are best surface with diamond. The Feed scale abrasive materials are usually important towards the process. Good sized grains remove material more quickly, while smaller grains generate a finer finish. The binders that hold these types of abrasive grains together consist of:

- Vitrified bonds, a glass-like bond formed of fused clay or feldspar
- Metal or single-layer bond systems for excellent abrasives

There are many types of grinding, but the four major industrial grinding processes are:

- Cylindrical Grinding.
- Internal Grinding.
- Center less Grinding.
- Surface Grinding.

In cylindrical grinding, the function piece rotates about a fixed axis and the surfaces machined and they are generally concentric to that axis of rotation. Cylindrical grinding generates an external surface that may be direct, contoured or tapered. The basic elements of a cylindrical grinder include a wheel head, which incorporate the drive motor and spindle; a cross-slide that goes the wheel head to and from the work part; a headstock, which contains, locates, and drives the work piece; and a tailstock, which holds the other end from the function.

The manufacturing procedure for Centre less grinding continues to be founded in the mass creation of slim, rotationally shaped components. Due to the complex set-up, which effects from the large level of sensitivity of this grinding procedure into a multiplicity of kinematical, geometrical, and dynamical influence parameters, Cylindrical grinding is rarely applied within just limited-lot production. The significant characteristics of this grinding process are the coexisting guidance and machining of the work piece upon its periphery. Cylindrical grinding is a vital process to get final machining of elements requiring smooth surfaces with precise tolerances. As in comparison with other machining procedures, grindings costly procedure that needs to be minimized under optimal circumstances. Although widely used in industry, grinding remains maybe the least understood of all machining processes. The major operating parameters that influence the output reactions, metal removal rate, surface area roughness, tool wear and surface damage etc., will be: (i) wheel parameters: abrasives, grain size, binder, quality, structure, dimension and condition and so forth, (ii) Work piece parameters many of these as fracture mode, mechanized properties and chemical structure, etc., (iii) Process guidelines such as depth of cut, work speed, feed rate, dressing condition, and so on., (IV) machine parameters: stationary and dynamic characteristics, stand system and spindle program and so forth The proposed work takes the following input processes variables namely Work speed, feed rate and depth of cut.

II. LITERATURE REVIEW

By referring Dadaso D, Mohite, Neeraj Tiwari, Sandeep Sontakke, Udayshankar Mishra (2017) concludes that Surface Roughness (Ra), out of four dressing parameters dressing cross feed rate is the most influencing factor for EN19 work material depend on dressing depth of cut, drag angle of dresser and number of passes were having lower influence.

Ankit Kumar, Ravi Patel, Jitendra Kumar Verma(2016) States that, Statistically designed experiments based on Taguchi method are performed using L9 orthogonal array to analyze surface roughness. The results giving from analysis of Signal Noise ratio and ANOVA were in close agreement. Depth of Cut and Grain Size are most significant process parameters while cross feed is least significant as compared to Grain Size and Depth of Cut.

Naresh Kumar, Himanshu Tripathi, Sandeep Gandotra (2015) proposed that, The input parameters like speed of grinding, feed, has a significant effect on surface roughness, whereas depth of cut has the least effect on surface roughness of C40e steel.

OBJECTIVE

The main objective of this work is to predict the grinding behavior and achieve optimal operating processes parameters. Softwares is utilized which integrates these various models to simulate what happens during cylindrical grinding processes. The main purpose in any machining process is to maximize the Metal Removal Rate (MRR) and to minimize the cylindrical roughness (Ra). In order to optimize these values Taguchi method is used.

III. METHODS AND MATERIAL

The aim of experimental work is to investigate the effect of grinding parameters with the process parameters of cutting speed, feed rate and Depth of cut influencing the metal removal rate of AISI EN19 Mild Steel.

Taguchi Method

The Taguchi approach involves reducing the variance in a process through robust design of tests. The objective of the technique is to produce high top quality product at low expense to the manufacturer. The Taguchi method was created simply by Dr. Genichi Taguchi of Japan who maintained that variation. Taguchi method developed for designing tests to find how several parameters affect the mean as well as variance of a process performance characteristic that shows how the method is work. The trial and error design proposed by Taguchi involves using orthogonal arrays to organize the guidelines affecting the levels and process where will need to be varies. Instead of needing to test all options such as the factorial design, the Taguchi method tests pairs of combinations. This permits for gather the required data to determine which usually factors most affect item quality with a minimal amount of experimentation, therefore saving resources and period. The Taguchi method is usually is definitely best used when presently there are an intermediate quantity of variables, few relationships, and once just a few variables contribute considerably.

The Taguchi arrays can easily be derived. Small arrays can be slow by hand; large arrays could be produced from deterministic algorithms. The arrays are selected simply by number of parameters because a variables and the number of levels like a states. This is even more explained later in this kind of article. Analysis of difference on the collected info from the taguchi technique of experiments works extremely well to select new parameter principles to optimize the overall performance characteristic. The data through the arrays can be reviewed by plotting the info and performing a visible analysis, ANOVA.

The Taguchi approach permits a comprehensive understanding of the combined and specific process parameters from a minimum quantity of simulation tests. The quality engineering approach proposed by Taguchi offers a new experimental technique in which an altered and standardized kind of style of experiment is utilized. In other words, the Taguchi approach is a kind of DOE with special application concepts. The Taguchi technique assists to study effect of many factors (variables) upon the desired quality most economically. By learning the effect of specific factors on the outcomes on grinding parameters, the best factor blend can easily be determined. Taguchi patterns experiments using especially built tables known as "orthogonal array" (OA). OA is usually the matrix of quantities arranged in columns and rows. The make use of these types of tables makes the type of experiments very easy and steady and it needs relatively lesser number of experimental trials are executed to study the complete parameter space. As a result, period, cost, and labor cutting down can be achieved. The Taguchi method employs a generic signal-to- noise (S/N) rate to quantify the current variance. These S/N ratios will be meant to be applied as measures of the effect of noise elements on performance characteristics. S/N ratios take into accounts both amount of variability in the response info and closeness from the typical response to target.

The experimental results are changed into a sign to noise (S/N) ratio. Taguchi recommends the use the S/N ratio to gauge the quality characteristics deviating through the desired values. Usually, you will discover three categories of top quality characteristic in the evaluation of the S/N percentage, i.e. the-Smaller-the-better, the-higher-the better, and the nominal-the-better. The S/N ratio intended for the each level of process parameters is calculated depending on the S/N evaluation. Regardless of category of the quality characteristic, a larger S/N ratio corresponds to quality characteristics. Therefore, the maximum degree of the process guidelines is the level with the greatest S/N percentage.

Taguchi proposed the use dropping function to measure the deviation of the top quality characteristic through the desired benefit. The value of the typical the standard loss function is additional transformed into a signal-to-noise (S/N) ratio. Usually, the three types of the top quality characteristic in the evaluation of the S/N percentage, i.e. the lower-the-better, the larger-the-better, and the more-nominal-the-better. The S/N percentage for every single degree of process guidelines is computed based upon the S/N analysis. Irrespective is the category of the high quality characteristic, a bigger S/N ratio corresponds to better quality characteristic. As a result, optimal level of the process parameters is the level with the greatest S/N ratio. Further, a statistical analysis of difference (ANOVA) is performed to see which process guidelines are statistically significant. The optimum blend from the procedure parameters can then become predicted. Finally, an test is conducted to confirm the perfect process guidelines obtained from the procedure variable design.

A. Experimental Work

Fig 1 : CNC Cylindrical Grinding Machine

Fig 2 : Surface Roughness Tester.

B. Taguchi Method of Orthogonal Arrays

Number of Parameters-3

1. Rotational speed- e.g. A, B, C
2. Feed- e.g. P, Q, R
3. Depth of cut- e.g. L, M, N

Here there are total three levels for each parameter.

C. Material general properties

Alloy EN19 is a molybdenum contains, low carbon ASS with increased in addition to that chromium, nickel, and molybdenum for better corrosion resistance and increased resistance to chemical attack for sulfurous, acetic, formic, citric, and tartaric acids. Due to low carbon content, EN19 also provides resistance to sensitization when welded and higher creep, tensile strength and stress to rupture at elevated temperatures. This material is non-magnetic in the annealing condition but may become magnetic after welding.

D. Applications

- Alloy EN19 is commonly used to industries gear, gears, shafts, spindles, gears, bolts, studs and a wide variety of applications where a good quality high tensile steel grade. Some core applications that use Alloy EN19 include:
- Automotive gears and parts
- Shafts
- Towing pins
- Load bearing tie rods
- Oil & Gas industry applications

IV. RESULTS AND DISCUSSION

S/N Ratio Analysis: Signal-to-noise (S/N) ratio is then derived from the loss function. There are three types of S/N ratios depending upon type of characteristics Lower is better (LB), nominal is best (NB), higher is better (HB). In Material removing Rate higher value is required. Therefore "HB" is chosen for the MRR similarly in Surface Roughness smaller value is required. Therefore "LB" is chosen for the Ra, and it is calculated as the logarithmic transformation of the loss function as shown below. With the Signal to noise and ANOVA analyses, the optimum combination of the process parameters can be predicted.

In this study, in order to maximize the MRR higher is better S/N ratio is chosen and minimize the Ra, lower is better S/N ratio is chosen.

$$\frac{S}{N} = -10 \log \frac{1}{n}\sum_{i=1}^{n} \frac{1}{Yi^2} \ldots\ldots\ldots\ldots 1$$

Where, n = number of repetitions or observations yi = the observed data.

Table 1 : Layout for experimental design.

Exp. No.	Speed (rpm)	Feed (mm/rev)	DOC (µm)	MRR	Ra
1	1000	0.093	0.2	9.23	0.63
2	1000	0.073	0.4	13.84	0.75
3	1000	0.130	0.3	13.22	0.76
4	780	0.073	0.3	7.78	0.71
5	780	0.093	0.4	11.30	0.52
6	780	0.130	0.2	4.61	0.70
7	560	0.073	0.2	13.04	0.75
8	560	0.093	0.3	6.00	0.50
9	560	0.130	0.4	6.66	0.33

Table 2: S/N Ratio analysis of MRR

Exp. No.	Speed (rpm)	Feed (mm/rev)	DOC (µm)	MRR	S/N Ratio
1	1000	0.093	0.2	9.23	19.30
2	1000	0.073	0.4	13.84	21.93
3	1000	0.130	0.3	13.22	20.42
4	780	0.073	0.3	7.78	17.82
5	780	0.093	0.4	11.30	21.06
6	780	0.130	0.2	4.61	13.27
7	560	0.073	0.2	13.04	19.30
8	560	0.093	0.3	6.00	15.56
9	560	0.130	0.4	6.66	16.47

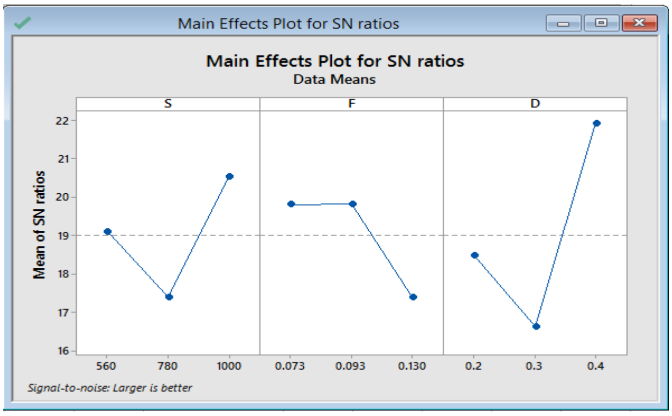
Higher value of Signal to Noise ratio corresponds to optimum level of input parameter. From table 2 it is cleared that the higher value of S/N ratio comes at Speed 1000rpm, feed 0.073mm/rev and depth of cut 0.4µm.

Table 3 : S/N Ratio analysis of Ra

Exp. No.	Speed (rpm)	Feed (mm/rev)	DOC (µm)	Ra	S/N Ratio
1	1000	0.093	0.2	0.63	3.88
2	1000	0.073	0.4	0.75	2.05
3	1000	0.130	0.3	0.76	2.38
4	780	0.073	0.3	0.71	2.98
5	780	0.093	0.4	0.52	5.68
6	780	0.130	0.2	0.70	3.10
7	560	0.073	0.2	0.75	2.50
8	560	0.093	0.3	0.50	6.03
9	560	0.130	0.4	0.33	6.136

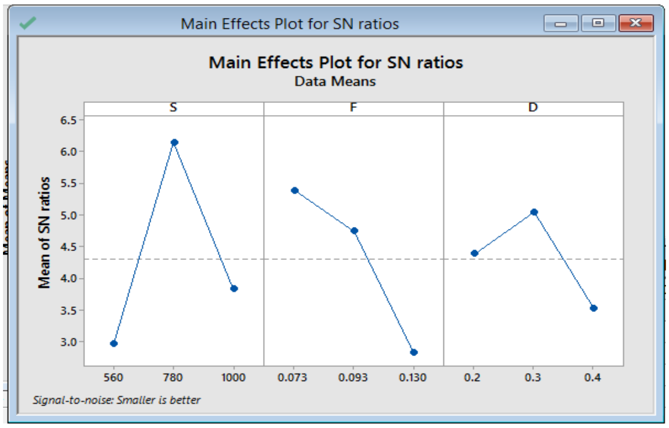
Higher value of Signal to Noise ratio corresponds to optimum level of input parameter. From table 3 it is cleared that the higher value of S/N ratio comes at Speed 560rpm, feed 0.130mm/rev and depth of cut 0.4µm.

Table 4 : Response table for signal to noise ratio larger the better (MRR)



Level	Speed(m/min)	Feed(mm/rev)	Doc(mm)
1	19.10	19.81	18.47
2	17.39	19.82	16.62
3	20.53	17.39	21.93
Delta	3.15	2.43	5.31
Rank	2	3	1

Table 5 : Response table for signal to noise ratio smaller the better(Ra)



Level	Speed(m/min)	Feed(mm/rev)	Doc(mm)
1	2.965	5.381	4.377
2	6.136	4.733	5.034
3	3.831	2.819	3.521
Delta	3.171	2.562	1.514
Rank	1	2	3

Analysis of Variance (ANOVA): ANOVA is objective decision making for determining the average performance of group of parameter tested and it is helpful in determining the significance of all parameters. The analysis of variance was used to identify the important input parameters which effects on MRR and Ra. Once the experiment has been conducted, the

ANOVA is carried out using the results of the experiments by making use of minitab18 software. The analysis of the experimental data is done using the software MINITAB 18 specially used for design of experiment applications. In order to find out statistical Significance of various factors like Speed, Feed, Depth of cut and their interactions on Material Removing Rate MRR and Surface Roughness Ra, analysis of variance (ANOVA) is performed on experimental data

Table 6. Analysis of variance for S/N Ratios on MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
speed	2	14.90	14.90	7.449	0.38	0.724
feed	2	21.12	21.12	10.560	0.54	0.650
doc	2	18.85	18.85	9.424	0.48	0.675
Residual Error	2	39.14	39.14	19.570		
Total	8	94.01				

Table 7. Analysis of variance for S/N Ratios on Ra

Source	DF	Seq SS	Adj SS	Adj MS	F	P
speed	2	17.774	17.774	8.887	2.51	0.285
feed	2	9.486	9.486	4.743	1.34	0.427
doc	2	14.284	14.284	7.142	2.02	0.331
Residual Error	2	7.071	7.071	3.536		
Total	8	48.615				

The results of ANOVA are shown in table 6 and table 7 it is clear that the parameters Speed Feed and Depth of Cut significantly affect the MRR and Ra. Larger F- value indicates that the variation of process parameters makes a big change on the performance. The last column of the table shows that P-value for the individual control factors. Smaller the P-value, greater the significance of the parameter.

The ANOVA table for S/N ratio Table 6 indicate that, the Speed (P=0.724), Feed (P= 0.650) and Depth of cut (P=0.675) in this order, are significant control factors affecting MRR. It means, the Feed is the most significant factor followed by Speed and Depth of Cut.

The ANOVA table for S/N ratio Table 7 indicate that, the Speed (P=0.285), Feed (P= 0.427) and Depth of cut (P=0.331) in this order, are significant control factors affecting Ra. It means, the Speed is the most significant factor followed by feed and Depth of Cut

1. Regression analysis

The regression equation generated by minitab18 software is,
The regression equation for MRR is,
MRR = 16.3 - 0.00386 speed - 23.1 feed - 4.9 doc
MRR = 16.3 – (0.00386 X 560) – (23.1 X 0.093) – (4.9 X 0.3)
MRR = 10.5201

The regression equation generated by minitab18 software is,
The regression equation for Ra is,

Ra = 0.324 + 0.000174 speed + 2.11 feed - 0.117 doc

Ra = 0.324 + (0.000174 X 780) + (2.11 X 0.073) – (0.117 X 0.3)

Ra = 0.5786

V. CONCLUSION

- Taguchi method is most efficient method for Optimization by using this method we can find best optimal combination among number of experiments.
- Process parameters like Speed, Feed, and Depth of cut are important for maximization of Material Remove rate (MRR) and minimization of Surface Roughness (Ra).

- For Material Remove rate (MRR) the most influencing parameter is feed followed by Depth of cut and Speed.
- For Surface Roughness (Ra) the most influencing parameter is Speed followed by Depth of cut and Feed.
- Optimal Combination for Material Remove rate (MRR) is,
  Optimal combination for MRR
  Speed - 1000 m/min
  Feed - 0.073 mm/rev Depth of Cut - 0.4 μm
- Optimal Combination for Surface Roughness (Ra) is, Optimal combination for Ra.
  Speed - 560
  m/min Feed - 0.130
  mm/rev Depth
  Of Cut - 0.4 μm

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