Optimization of Cylindrical Grinding Machine Parameters for Minimum Surface Roughness and Maximum MRR

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Abstract

Cylindrical grinding is very important process to improve quality of the component and to get precision dimensions with smooth surface finish. In the manufacturing sector, producing smooth surface finish plays an important role. To fulfill this smooth finish, surface grinding process is mostly used in which the parameters to be considered are surface quality and metal removal rate. Several factors which include depth of cut, wheel grade, wheel speed, material properties and table speed affects the machining process economics. This paper mainly focuses on developing the empirical models using response surface methodology for surface roughness and metal removal rate by considering control factors as wheel speed, table speed and depth of cut. The main objective of using Response surface methodology (RSM) on surface grinding operation of EN19 steel is to find optimum machining parameters which leads to minimize surface roughness and maximum metal removal rate. For conducting the experiment EN19 material was chosen due to various applications in automobile and mechanical components. While experimenting on cylindrical grinding machine having silicon carbide wheel L9 Orthogonal array with input variables for analysis and for optimization Taguchi method was implemented. The optimization model developed could be beneficial to many different manufacturers to get right combination of matching parameters to achieve minimum surface roughness.

Keywords- Cylindrical grinding, Grinding, Taguchi Method, ANOVA, Modeling, Optimization

I. INTRODUCTION

Cylindrical grinding machine is used in machining of components for smooth surface finishing and to get close tolerances. To improve surface properties and mechanical properties with extended life of object optimal conditions are necessary for manufacturing. Although grinding operation has great importance in total manufacturing process still there optimal parametric values are not accounted by many manufacturers.

Most common influencing parameters of grinding are grinding wheel, speed, feed, depth of cut. For present work the included parameters are Speed, Feed, Depth of cut and another one hardness of material.

Analysis of variance (ANOVA) has been used for knowing the most exciting parameter of the included ones. For designing the experimentation Taught method was implemented and for optimization ANOVA. Various output parameters are involved to achieve optimal value for example chemical composition of grinding wheel, various grades and grains used on grinding wheel, Type of abrasive, Curing speed, Feed rate ,Depth of cut and many. From these involved parameters surface finish and metal removal rate gives great response at output in the production for quantity of product.

In this Study, four important parameter of grinding machine these are depth of cut, feed rate, machine speed, material hardness were selected as variables parameters and other parameters were fixed. Taguchi design methodology is used to determine optimum condition having minimum surface roughness and maximum MRR on EN19 steel bar using cylindrical grinding machine. Experimental results were used to find analysis of variance (ANOVA) which explains the significance of grinding parameters .The second order mathematical models in terms of Cylindrical grinding parameters were developed for surface roughness and MRR

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depending on the experimental results. Taguchi approach was corroborated on different levels to verify its effectiveness on proposed work.

A. Problem Statement

Mathematical Modeling and optimization of grinding parameters for maximum material removal rate and minimum surface roughness.

B. Objective

Our aim in this project is to make Mathematical Modeling and Optimization of Grinding Parameters for Minimum Surface Roughness and Maximum MRR.

C. Methodology

For present study, efforts were made to find experiment values of parameters on grinding machine and they were measured on the basis of minimum surface roughness (Ra) for EN19 cylindrical bar. For this experimentation, parameters were used at three different levels in order to show the efficacy of the parameters at optimum level to increase quality with production. L9 orthogonal array is used for experimental design to observe the interaction of parameters with surface properties.

The grinding performance is significantly affected by, the important parameters in the grinding machine like feed, depth of cut, work piece material. The effect of these parameters on the grinding machine is measured in terms of the surface finish produced on the work piece during subsequent grinding operation. In the present work, experimental results were used to find analysis of variance (ANNOVA) which explains the significance of the proposed parameters.

A Mathematical model is developed to get correlation between input grinding parameter and the obtained output parameters.

II. LITERATURE REVIEW

Witold F. Habrat (2016), the study presents selected results of research in the field of grinding cemented carbide with the use of diamond grinding wheels. In the fundamental experiments two different types of diamond grinding wheels were used. The diamond grinding wheels were varied by bonding material. In the investigation, response surface method was used to predict grinding force components during grinding of the ductile cemented carbide CTS20D work piece material. The grinding speed, depth of cut and feed rate were considered as input process parameters. Furthermore, the ANOVA (analysis of variance) was employed for checking the developed model results. The results revealed that grinding with the use of resin bond grinding wheel provides significantly lower grinding force components during the process. [1]

Dadaso D. Mohite (2016) the ability of a grinding wheel to perform is significantly affected by the way in which the wheel is dressed. The four important parameters of blade type multi point diamond dressing operation are, dressing depth of cut, dressing cross feed rate, drag angle of dresser and number of passes. The effect of these parameters is measured in terms of surface of work piece during subsequent grinding operation. In this work, empirical models are developed for surface roughness by considering selected four parameters of dressing as control factors using Taguchi design methodology. The mathematical models in terms of dressing parameters were developed for surface roughness on the basis of experimental results. [2]

Pawan Kumar (2013) this study surface grinding is the most common process used in the manufacturing sector to produce smooth finish on flat surfaces. Surface quality and metal removal rate are the two important performance characteristics to be considered in the grinding process. The main purpose of this work is to study the effects of abrasive tools on EN24 steel surface by using three parameters (Grinding wheel speed, table speed & Depth of cut). This study was conducted by using surface grinding machine. In this work, empirical models were developed for surface roughness and metal removal rate by considering wheel speed, table speed and depth of cut as control factors using response surface methodology. In this Response surface methodology (RSM) was applied to determine the optimum machining parameters leading to minimum surface roughness and maximum metal removal rate in Surface grinding process. [3]

Pereverzev P.P (2016) an important and intractable problem of domestic engineering industry is the low productivity of operations performed on CNC machines. The reason for this is the absence of standards and methodologies for the design of optimal cycles for CNC machines. As a result, in practice, one has to manually choose processing modes which presents no solution to the problem of low productivity, as this method generates losses, particularly in relation to automated production intra grinding processing on CNC machines in series production. To solve this problem the research, primarily, proposes a methodology for the design of optimal multivariable stepwise cycles internal grinding processing, allowing to calculate as follows: optimal values of the radial flow at all stages of the cycle; the optimum value of the axial feed at all stages of the cycle; optimal allocation deduct allowance on the steps of the cycle for radial and axial feeds, which provide the minimum cycle time, given the technological constraints of the objective function.[4]

M. Ganesan. (2000) Recently 304 stainless steel finds many applications like Automotive, Aerospace, Nuclear, Chemical and Cryogenics. The cylindrical grinding parameters on 304 stainless steel are conducted using Taguchi design of experiments of L9 orthogonal array was selected with 3 levels with 3 factors and output parameter of Surface Roughness is measured. The quality of the surface describes the relationship between the cutting speeds, feed rate, depth of cut and surface roughness are measured. High quality of the machining is done using the cylindrical grinding operation. [5]

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Sandeep Kumar (2015) this article grinding process is surface finishing process generally used to smoothen the surfaces by removing the limited quantity of material from the already machined surfaces. Cylindrical grinding or abrasive machining is the most popular machining process of removing metal from a work piece surface in the form of tiny chips by the action of irregularly shaped abrasive particles. In the present study, Taguchi method or Design of experiments has been used to optimize the effect of cylindrical grinding parameters such as wheel speed (rpm), work speed, feed (mm/min.), depth of cut and cutting fluid on the Material Removal Rate of EN15AM steel. Material removal rate measurements were carried out during the machining process on the work piece. [6]

III. OPTIMIZATION

Fig. 1: Grinding Machine used for experiment

Fig. 2: Grinding of work piece

Table 1: Grinding Parameter

Grinding Parameter	*Depth of cut in mm (D)*	*Feed Rate in mm/rev (f)*	*Speed rpm (N)*	*Material Hardness (H)*
Level 1	*20*	*0.06*	*145*	*30*
Level 2	*30*	*0.12*	*247*	*40*
Level 3	*40*	*0.18*	*415*	*50*

Total 9 nine experiments were performed while altering each parameters at three different levels.

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The variability of the quality characteristic can be expressed by signal to noise ratio. The term signal and noise represent the desirable and undesirable values for characteristics.
Operations conducted as per the following sequence shown in table

Table 2: Experimental Data for MRR

Expt. No.	*D*	*f*	*N*	*H*	*MRR*	*S/N ratio*
1	*20*	*0.06*	*145*	*30*	*0.07692*	*-22.2789*
2	*20*	*0.12*	*247*	*40*	*0.11160*	*-19.0467*
3	*20*	*0.18*	*415*	*50*	*0.07744*	*-22.2207*
4	*30*	*0.06*	*247*	*50*	*0.17260*	*-15.2592*
5	*30*	*0.12*	*415*	*30*	*0.25840*	*-11.7541*
6	*30*	*0.18*	*145*	*40*	*0.2363*	*-12.5307*
7	*40*	*0.06*	*415*	*40*	*1.444*	*3.19134*
8	*40*	*0.12*	*145*	*50*	*1.2288*	*1.78962*
9	*40*	*0.18*	*247*	*30*	*2.0177*	*6.09713*

MITUTOYO surf test SJ-210 was used to measure Surface roughness. The experimental Ra values and Signal-to-noise ratio (S/N ratio) values.

Fig. 3: MITUTOYO surf test SJ-210

Table 3: Experimental Data for surface roughness

Exp. No.	*D*	*f*	*N*	*H*	*Ra*	*S/N ratio*
1	*20*	*0.06*	*145*	*30*	*0.6490*	*3.75511*
2	*20*	*0.12*	*247*	*40*	*0.9420*	*0.51898*
3	*20*	*0.18*	*415*	*50*	*0.6534*	*3.69642*
4	*30*	*0.06*	*247*	*50*	*0.6164*	*4.20275*
5	*30*	*0.12*	*415*	*30*	*0.9228*	*0.69785*
6	*30*	*0.18*	*145*	*40*	*0.8436*	*1.47727*
7	*40*	*0.06*	*415*	*40*	*0.7498*	*2.50109*
8	*40*	*0.12*	*145*	*50*	*0.6380*	*3.90359*
9	*40*	*0.18*	*247*	*30*	*1.0476*	*-0.4039*

IV. MEAN EFFECT PLOT FOR S/N RATIO

1) Mean effect plot for S/N ratio for MRR .Signal to noise ratio is by larger is better.

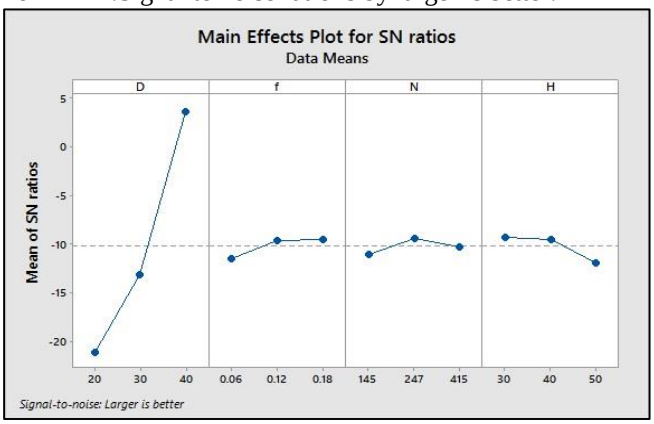

Fig. 4: Main effect plot for MRR

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MRR increases with increase in the depth of cut and feed rate .MRR decreases with increase in hardness valve.

2) Mean effect plot for S/N ratio for surface roughness. Signal to noise ratio is by smaller is better.

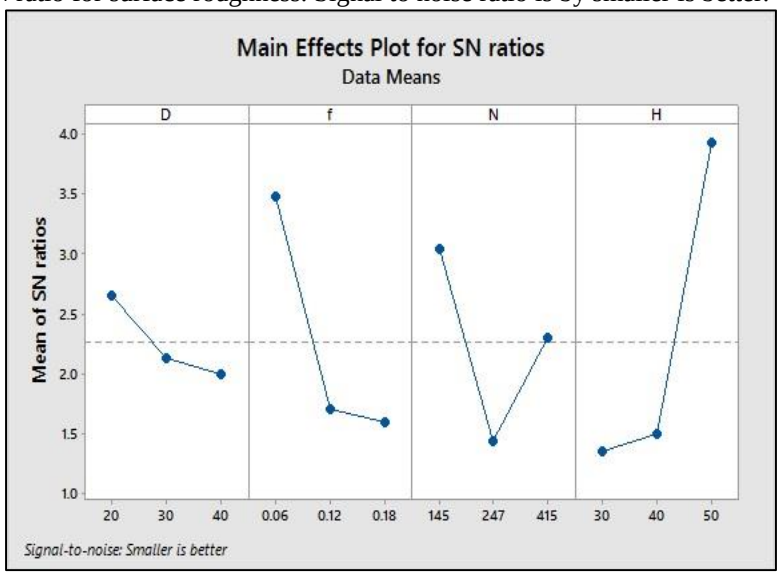

Fig. 5: Main effect plot for Ra

Surface roughness increase with increase in hardness .Surface roughness decrease with decrease in depth of cut.

V. ANALYSIS OF VARIANCE

Analysis of variance (ANOVA) is a collection of statistical models.
Analysis of variance is an incredibly effective method for analyzing the data obtained from properly and scientifically designed experiments. Analysis of variance is a statistical method used to interpret experimental data and make necessary decision.

ANOVA is used to determine the significance of controlled factors. The most significant factors is calculated by using F-ratio. From ANOVA TABLE Hardness is the most significance factor of the process parameters on the surface roughness.

Table 3: Experimental Data for ANOVA model of surface roughness

Source	*DF*	*Sum of Square*	*Variance*	*F-ratio*	*p*
D	*2*	*0.01946*	*0.06489*	*0.2332*	*2.2*
f	*2*	*0.17325*	*0.05775*	*2.0756*	*20.15*
N	*2*	*0.11419*	*0.03806*	*1.3681*	*13.28*
HRC	*2*	*0.302437*	*0.100812*	*3.62336*	*35.17*
Error	*18*	*0.2504*	*0.0006*		*29.12*
Total	*26*	*0.85976*			

VI. INTERACTION PLOTS

1) The effect of one factor depends on the level of the other factor. An interaction plot is used to visualize possible interactions.

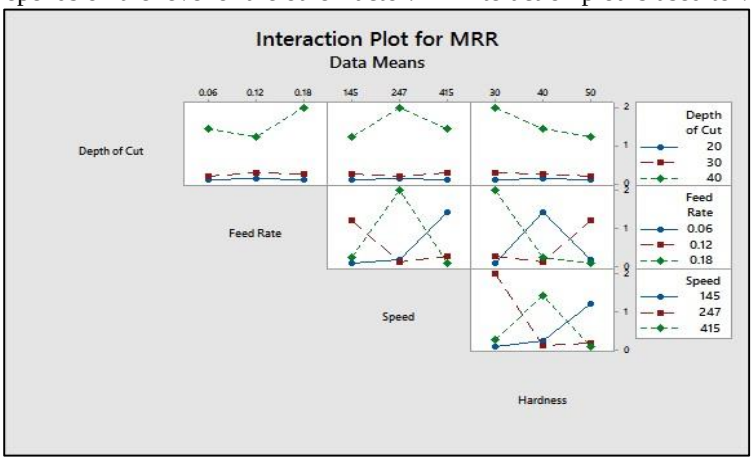

Fig. 6: Interaction plot for MRR

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2) Interaction plot between all parameter such as depth of cut, feed rate, Spindle speed and hardness of the material.

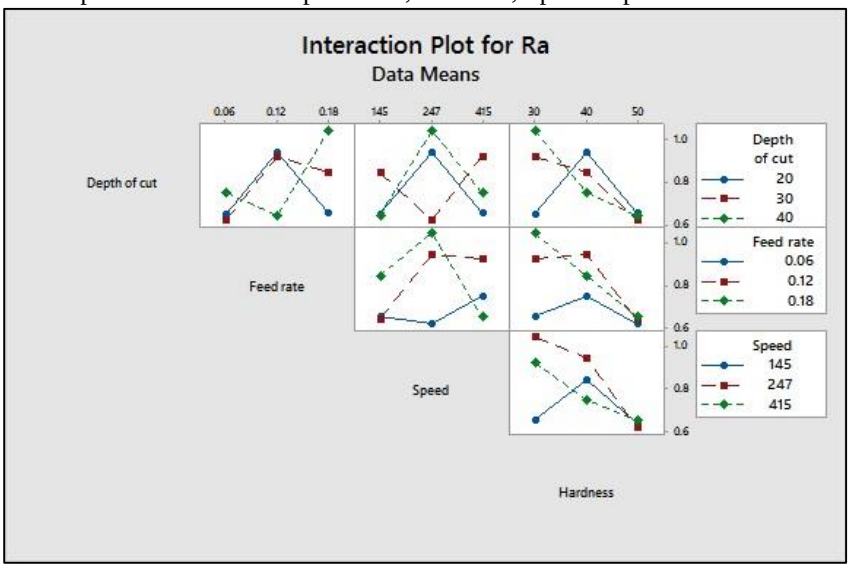

Fig. 7: Interaction plot for Ra

VII. CONTOUR PLOT

Contour plot is used to find the potential relationship between three variables. Contour plots is used to display the 3-dimensional relationship in two dimensions, with x- and y-factors. Hardness is plotted on the x- and feed is plotted on y-scales and response values represented by contours.

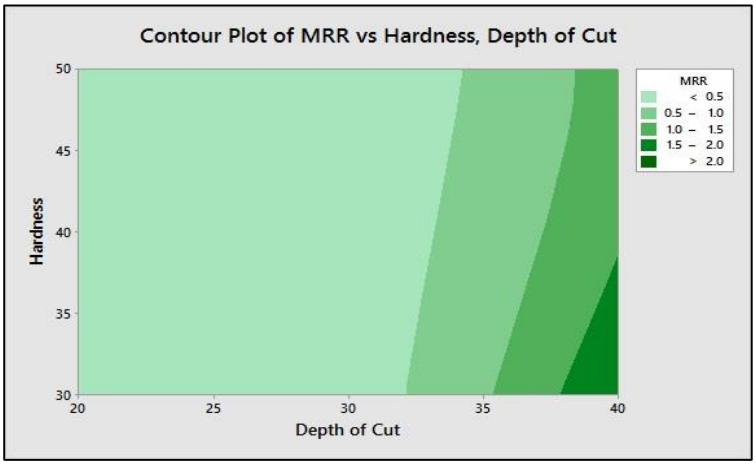

Fig. 8: Contour plot for MRR

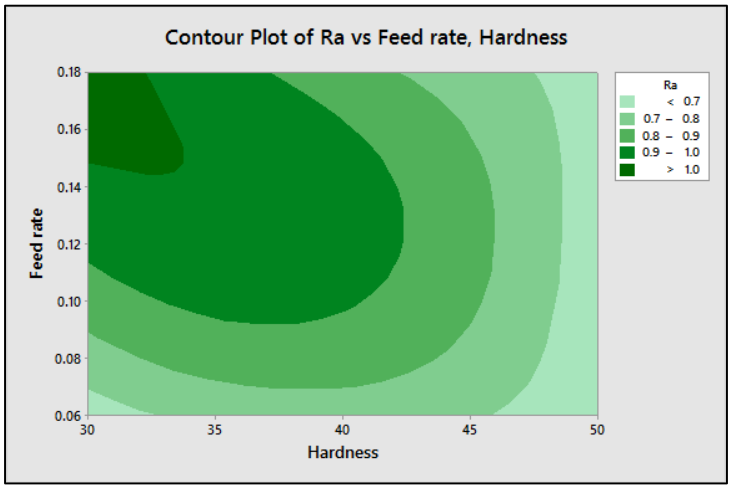

Fig. 9: Contour plot for Ra

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VIII. RESULT

The confirmation experiment is a final step in verifying the conclusions from the previous round of experimentation. The optimum conditions are set for the significant parameters and a selected number of tests are run under specified conditions. The confirmation experiment is a crucial step and is highly recommended to verify the experimental conclusion. The optimum valve for surface roughness is 20mm depth of cut, 0.18mm/rev is the feed rate, 415rpm is the spindle speed, hardness is 50 HRC. The surface roughness increases with increase in Hardness value.

IX. CONCLUSIONS

This paper present that it has use taguchi method to decide the optimal process parameter. The output parameter is surface roughness.

1) The hardness is the most dominating factor on surface roughness of work piece followed by Feed rate. The percentage contribution for feed rate is 20.15%, and hardness is 35.17% calculated from ANOVA method.
2) The surface roughness depend on hardness of material It is recommended that hardness is 50HRC.
3) The optimum valve for surface roughness is 20mm depth of cut, 0.18mm/rev is the feed rate, 415rpm is the spindle speed , hardness is 50 HRC.

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