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PARAMETRIC OPTIMIZATION FOR SURFACE ROUGHNESS DURING SURFACE GRINDING ON AISI52100 STEEL USING TAGUCHI APPROACH

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ABSTRACT

Surface grinding is commonly used in the manufacturing industry where in little stock is being removed from hard materials. Major factors controlling this process are grinding wheel type, wheel grain size, table speed, table feed, Wheel speed, depth of cut etc., This paper investigates a systematic approach to determine the effect of process variable such as grinding wheel type, depth of cut and grinding wheel speed. The experimentation is conducted by using Taguchi's mixed design (orthogonal array) and by using Taguchi's analysis the optimal setting of process parameters was found for a gives response characteristic i.e. Surface roughness. By using ANOVA (analysis of variance) the contributing effect of each variable for a gives response is depicted. In this work AISI 52100 steel of 100 mm length, 30 mm breadth and 30 mm thickness was used .

Keywords- *Surface grinding, AISI 52100 steel, Taguchi method, Analysis of variance(ANOVA), Surface roughness.*

I. INTRODUCTION

Grinding is a metal removing process performed with the help of grinding wheel. It is employed for finishing various parts such as engine crank-shafts, splined shaft, lathe guide ways, long pipes, worms, toothed gears, pinions, racks and surfaces. Surface grinding is the process of producing flat surfaces by means of revolving abrasive wheel. According to the shape of the table and its movement, surface grinding machines can be divided into two categories – planer type and rotary type. In planner-type surface grinders, the table is rectangular in shape and traverses under the wheel. In rotary – type surface grinders, the table is circular in shape and rotates under the wheel. According to the position of the spindle, surface grinder can also be classified as a) horizontal spindle and b) vertical spindle.

The surface quality produced in surface grinding is influenced by various parameters such as wheel parameters – I. abrasives, grain size, grade, structure, binder, shape and dimension; ii. Work piece parameters – fracture mode, mechanical properties and chemical composition; iii. Process parameters –wheel speed, depth of cut, table speed and dressing condition; IV. Machine parameters – static and dynamic characteristics, spindle system, and table system.

The present paper takes the following input processes parameters viz. wheel type, wheel speed, and depth of cut. The main objective of this paper is to show how our knowledge on grinding process can be used to predict the grinding behavior and achieve optimal operating processes parameters. The knowledge is mainly in the form of physical and empirical models which describe various aspects of grinding process. The main objective in any machining process is to lessen the surface roughness (Ra). In order to optimize these values, Taguchi method is used. Taguchi's L18 orthogonal array: The effects of all the input parameters on the output responses have been studied using analysis of variance (ANOVA). The effect of variation in input parameters has been studied on the output responses. Plots of S/N ratio have been used to decide the best relationship between the responses and the input parameters, in other words, optimum set of input parameters for minimum surface roughness are determined.

The main objectives of the paper are as follows:

1. To examine and optimize the grinding process Parameters (type of grinding wheel, spindle speed, and depth of cut) for the enhancement of the surface finish on AISI 52100 steel so as to work out optimum set of input parameters for minimum surface roughness by using ANOVA method.
2. To confirm the validity of optimum set of input parameters obtained by conducting verification experiments.

II. LITERATURE SURVEY

Kumar et al. [1] aimed at finding the optimal material removal and effect of process parameters of cylindrical grinding machine by using Taguchi method. The experiment was designed using L-9 orthogonal array with three levels of each input variables. Analysis of variance (ANOVA) was used to investigate the effect of parameters. The authors found Analysis of variance (ANOVA) concluded that surface roughness is minimum at the 210 rpm, 0.11mm/rev feed, and 0.04mm depth of penetration.

Pal et al. [2] worked on optimization of grinding parameters for minimum surface roughness by Taguchi optimization technique. The authors conducted the experiments on a universal tool and cutter grinding machine with unusual grain sized aluminum oxide white grinding wheels, on different materials EN 24, EN 31 and Die steel. The work speed, material hardness and type of grinding wheel were chosen as input variables. The surface roughness was chosen as output parameter. An L9orthogonal array was use to design the experiments. When the speed of work piece was changed it was found that the surface roughness decrease when speed was changed from 100 to 160 rpm and again decrease while speed further increased to 200 rpm. The authors also accomplished that when grinding wheel grain size change from G46 to G60, the surface roughness decreases, but at grain size G80 roughness increases considerably.

George et al. [3] considered the surface roughness and its prediction in cylindrical grinding process based on taguchi method of optimization. The material hardness, work piece speed, and depth of cut were preferred as input parameters and surface roughness was preferred as response factor. An L9orthogonal array was used for designing the experiment. The experiments were conducted on En24, EN 31, and EN 353 materials with a cylindrical grinding machine. Surface roughness was measured by Mitotoyo surf test SJ-400 roughness tester. When the work piece speed was greater than before the surface roughness decreased. The surface roughness was also decreased while the depth of cut was increased from 10 to 20 µm. The minimum surface roughness obtain was 0.47 µm at work piece speed of120 rpm and when depth of cut was 20 µm.

Koshy etal. [4]tested face milling of AISID2 at 58HRC with Cbn tools and found acceptable tool life together with excellent surface finish in the range of 0.1 to 0.2 µm in Ra. However, the tools failed by fracture of the cutting edge and the authors compared the results with AISI H13 steel at a hardness of 52 HRC and detailed PCBN tool performance on the workpieces with a 40 cm3 material removal.

M jafar Hadad and M Hadi, 2013[5] stressed on the need to use MQL in grinding but found that the effect of MQL on grinding is minimal and suggested the usage of vegetable oil as coolant to have a good surface finish when compared to ester mixed coolant.

Brinksmeier [6] et. al. have investigated elastic bonded wheels for a grind-strengthening and super finished surface in a single step. Further, to achieve a high mechanical impact and to minimize the thermal effect of grinding process require a low cutting speed and showed that if chip thickness is constant, the chip formation mechanism shifts towards micro-ploughing and thus additionally increases the specific grinding energy.

Fathallah [7] et. al. have investigated for better surface integrity of AISI D2 steel by using sol-gel grinding wheel and cooling by liquid nitrogen comparatively with conditions using aluminium oxide and cooling with oil-based.

III. EXPERIMENT DETAILS

Work piece Material

The work piece material selected for investigations AISI 52100 steel. The work piece material are used is a rectangular plate of dimensions 30x30x70mm was taken and it was machined using Surface Grinder machine. The chemical composition of the AISI 52100 steel is as follows:

Table 1: Chemical Composition Of AISI 52100 Steel

Elements	**C%**	**Mn %**	**P %**	**S %**	**Si %**	**Cr %**
AISI 52100	0.95/1.10	0.25/0.45	0.025 max	0.025 max	0.20/0.35	1.30/1.60

Machining Process

The grinding was performed on special purpose surface grinding machine (fig 1) which is having grinding wheel of size 200 x 20 x 31.75 ID. The material of grinding wheel is aluminium oxide and Silicon carbide. The experiments were carry out as per the orthogonal array. After that surface roughness for various combinations of parameters was measured using MITUTOYO SURFTEST SJ-210 Machine which was shown In fig2

Design of Experiment

The experiment was planned using Taguchi's orthogonal array in the design of experiments, which help in reducing the number of experiments and to find out significant factors in a shorter time period. Dr. Genichi Taguchi (1980)

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has given a standard way to utilize the DOE to improve the quality of product and process for the design and manufacturing and also reduces the cost. In this present work three levels at four parameter (factors) has been employed to predict the optimal values, as shown in Table 2. These levels are decided by trial experiments conducted considering one factor at a time. The L18 orthogonal array for four factors and three levels is used in the present investigation. This L18 orthogonal array is selected to check the interactions between the factors as shown in Table 3.

Table 2 : Parameters and their levels for experiment

Grinding parameters	Symbols	Levels		
		1	2	3
Type of wheel	W	Al_2O_3	SiC	
Wheel Speed	S	1500	2000	2500
Doc	D	20	30	40

Fig 1: Surface Grinding machine

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Table 3: Orthogonal array of L18 showing 3 factor and 3levels and Experimental Details

Run No	Type of wheel	Wheel Speed	Doc	Surface Roughness (Ra)
1	Al_2O_3	1500	20	0.114
2	Al_2O_3	1500	30	0.148
3	Al_2O_3	1500	40	0.122
4	Al_2O_3	2000	20	0.09
5	Al_2O_3	2000	30	0.098
6	Al_2O_3	2000	40	0.106
7	Al_2O_3	2500	20	0.116
8	Al_2O_3	2500	30	0.091
9	Al_2O_3	2500	40	0.092
10	SiC	1500	20	0.092
11	SiC	1500	30	0.1
12	SiC	1500	40	0.078
13	SiC	2000	20	0.102
14	SiC	2000	30	0.098
15	SiC	2000	40	0.098
16	SiC	2500	20	0.096
17	SiC	2500	30	0.114
18	SiC	2500	40	0.116

Measurement of Surface Roughness

The surface roughness was checked using surface roughness testing machine. The surface roughness, Ra was measured in perpendicular to the cutting direction using a Surface Roughness tester. Surface roughness values are obtained from Mitutoyo Surface roughness tester for each experiment. Three reading are taken in each region, and the average of them were taken to minimize the error. Surface roughness (Ra) is use to record the output response.

The experimental results for surface roughness(Ra)obtained using Taguchi optimization technique are given in Table 4.

Table 4: Surface roughness of each experiment

Expo No	Surface Roughness
1	0.114
2	0.148
3	0.122
4	0.09
5	0.098
6	0.106
7	0.116
8	0.091
9	0.092
10	0.092
11	0.1
12	0.078
13	0.102
14	0.098
15	0.098
16	0.096
17	0.114
18	0.116

Fig 2: Mitutoyo surface roughness tester SJ-210

IV. RESULT AND DISCUSSION

Using Minitab 16 software, the S/N ratios were calculated and tabulated. The smaller the better phenomenon is chosen for surface roughness because surface quality will be high when the surface roughness values will be small. The larger is better phenomenon is chosen for material removal rate.

Analysis of signal to noise (S/N) ratio

In this section, impact of controllable factors is investigated using S/N ratio approach. A smaller value of surface roughness is usually required in metal machining. Therefore, the smaller the-better methodology of S/N ratio was in use for the aforesaid responses. Apart from the category of the performance characteristics, the high value ofS/N ratio corresponds to a better performance. Therefore, the optimal level of the process parameters is the level with the maximum S/N Ratio. Ra values with the corresponding S/N ratios are given in the Table 5.

Signal-to-noise ratio response table

Analysis of the influence of each control factor (W, N, D) on the surface roughness has been performed with a signal-to-noise ratio response table. Response tables of S/N ratio and means for Ra is shown in Table 5 and Table 6 respectively. It displays the S/N ratio at each level of the control factors and how it is changed when settings of each control factor are changed from one level to another.

Table 5. Response Table of Signal to Noise Ratios for Surface Roughness (Ra)

Level	Type	Speed	Doc
1	19.39	19.44	19.09
2	20.11	20.13	19.42
3		19.68	19.2
Delta	0.72	069	0.50
Rank	1	2	3

Prediction of optimal solution

The influence of each control factor can be clearly presented with response graphs (Fig 3). These figures reveal the level to be chosen for the ideal grinding parameters (the level with the highest point on the graphs), as well as the relative effect each parameter has on the S/N ratio (the general slope of the line). As seen in the S/N ratio effects graphs (Figs. 3), the slope of the line which connects between the levels can clearly shows

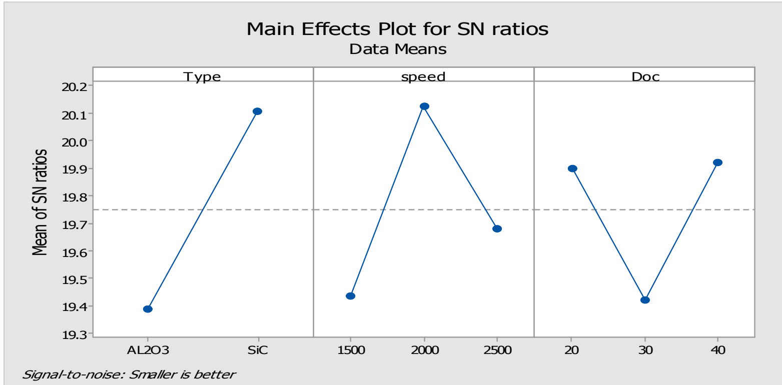

Figure 3: Main Effects plot for S/N Ratios

Analysis of variance (ANOVA)

The purpose of the ANOVA is to investigate which of the process parameters drastically affect the performance characteristics. This analysis provides the relative contribution of machining parameters in controlling the response of machining performance criteria i.e. surface roughness during 52100surface grinding. This is accomplished by separating the total unevenness of the S/N ratios, which is measured by the sum of the squared deviations from the total mean of the S/N ratio, into contributions by each of the process parameters and the error. Table6 shows the results of analysis of variance for the S/N ratio of the surface roughness.

Table 6. ANOVA results for S/N ratio of Surface Roughness

Source	Df	Sum Of Squares	Mean Squares	F- Ratio	% Contribution
Wheel Type	1	0.01165	0.01165	8.94	27.4246
Wheel Speed	2	0.009858	0.004929	7.57	23.20
Doc	2	0.0052862	0.0026	1.9966	12.44
Residual error	12	0.0156858	0.001307		36.94
Total	17	0.1836522	0.020486		100

SIGNAL FACTORS INFLUENCE ON RA FOR THE SURFACE GRINDING ON AISI 52100

The plots consisting of mean effects for S/N Ratio and interaction plot for means, smaller-is-better (S/N Ratio) is selected as an objective of performance characteristics for minimizing the target Ra of signal factors Wheel Type speed, and depth of cut. Among the machining parameters **Wheel type** is the most influence parameter. For surface roughness (Ra). The optimal parameter setting combination for AISI 52100 is shown in table 7

Table7. Optimized table obtained for AISI 52100

Control factors	Wheel Type	Wheel Speed	Doc(d) µ
Surface roughness (Ra) µm	SiC	2000	40

Analysis of Regression for Prediction of Surface roughness(SR):

1. Regression equation is the best fit equation between the input factors output response. That is to say the relationship between surface roughness and machining independent variables (weld current, weld time and diameter of electrode) is stated by the following way.
   SR = K + type(a) + wheel speed(b) + depth of cut(c)
   Where SR = Surface roughness, µm
   a, b, c = constants
   In order to facilitate the determination of constants and parameters the mathematical models of for the response (SR) are shown below. Analysis is done for the following regression equations to get predicted surface roughness values linearised by performing linear transformations are follows

   $SR= e^{-1.72}$x $Type^{-0.118}$xwheel $Speed^{-0.069}$x Depth of $cut^{0.005}$

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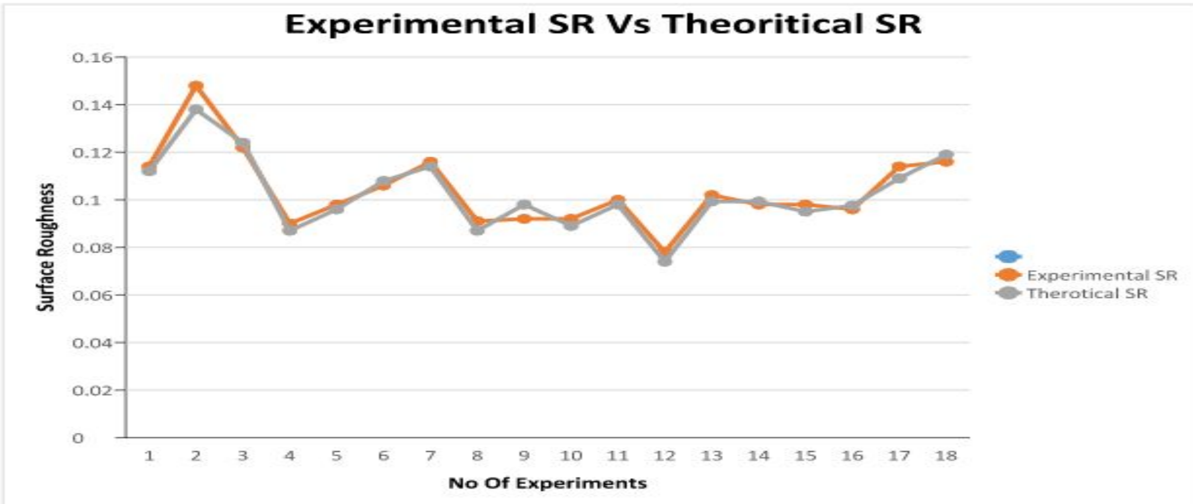
2. Regression predicted surface roughness(SR), are determined by performing regression analysis for the data shown in the table 8 using Minitab statistical tool. The regression equations obtained.

Table 8: Response Table for Predicted & Experimental Tensile Strength

S.NO	Type of wheel	Wheel speed (rpm)	Depth of cut (µm)	Experimental Surface roughness	Predicted Surface roughness
1	Al_2O_3	1500	20	0.114	0.112
2	Al_2O_3	1500	30	0.148	0.138
3	Al_2O_3	1500	40	0.122	0.124
4	Al_2O_3	2000	20	0.09	0.087
5	Al_2O_3	2000	30	0.098	0.096
6	Al_2O_3	2000	40	0.106	0.107
7	Al_2O_3	2500	20	0.116	0.114
8	Al_2O_3	2500	30	0.091	0.087
9	Al_2O_3	2500	40	0.092	0.098
10	SiC	1500	20	0.092	0.089
11	SiC	1500	30	0.1	0.098
12	SiC	1500	40	0.078	0.074
13	SiC	2000	20	0.102	0.0993
14	SiC	2000	30	0.098	0.0994
15	SiC	2000	40	0.098	0.095
16	SiC	2500	20	0.096	0.0976
17	SiC	2500	30	0.114	0.109
18	SiC	2500	40	0.116	0.119



V. CONCLUSIONS

Based on the analysis from this study following conclusions can be drawn.
1. The input parameter Wheel Type, has a major effect on surface roughness,
2.The optimized parameters for minimum surface roughness are wheel Type (SiC) grinding wheel speed (2000), Depth of cut (40µ).
3.The optimized minimum surface roughness is 0.098 µm.
4. The ANOVA re related that the percentage contribution of wheel type (27.42%) is the dominant parameter followed by wheel speed (23.20%), depth of cut (12.44%) for minimum surface roughness
5. Finally, the regression model is developed and is found that predicted values for surface roughness with reasonable degree of approximation. It is observed that the predicted values and experimental values of surface roughness is close to each other.

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