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Optimization of Surface Grinding Parameters Used in Improved Surface Integrity

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Abstract **- Surface grinding is one of the most extensively used procedures in industry for finishing materials. Different machining parameters have a great impact on a product's surface quality. While processing temperature increases and heat energy is generated, that may cause a few changes in the tool or work piece in chemical and physical properties. This will have an effect on the final product surface. Furthermore, numerous aspects of the machine, such as vibration, degree of freedom, and precise size, have an impact on the quality of the surface finish. The machining parameters, on the other hand, have a major role in determining the surface finish. The functional behavior of machined components can be enhanced by the grinding process, so proper selection of grinding wheel specifications and grinding parameters can result in improving the surface integrity. Because of this, understanding the surface integrity imparted by grinding is very important. This paper will display the results of an experimental study that were conducted to comprehensively investigate the effect of surface grinding input machining parameters on the formed surface quality. The experiments are running by changing the input machine parameters which are the feed rate, cutting speed, cooling method and depth of cut. The surface roughness and the cutting forces are the performance to be measured and assessed. It is concluded that the surface roughness (Ra) decreases with the increase in cutting speed and the coolant flow rate. But, as the feed rate and or the depth of cut increase the surface roughness (Ra) will also increase. The results of this investigation can be used to determine the optimal process parameters in order to obtain the required roughness quality of the produced surface in grinding of (ASTM A36) mild carbon steel.**

Keywords: Optimization of surface grinding parameters, Surface roughness, Taguchi, ANOVA, SNR.

I. INTRODUCTION

Accuracy of workpiece dimensions and surface integrity are important features for improving the performance of machined parts, thus mechanical and surface properties are essential for material characterization. Manufacturing companies confront a difficulty in meeting customer demands for high-quality goods with high strength, superior surface finishes, cheap costs, and little environmental impact [1]. Surface roughness is an important metric in many sectors since it indicates how well machined items are finished [2]. Controlling machining conditions such as cutting speed, cutting depth, and feed rate may improve the efficiency and effectiveness of manufacturing operations. Furthermore, surface roughness is a key factor in determining processing accuracy [3-5]. The impact of machining factors on the surface quality of metals, alloys, and composites has been explored by a number of researchers.

Mainly the last shaping step is grinding, which is used to achieve the appropriate surface roughness and fineness of the form features. A huge number of abrasive grains, dispersed on the outer cylindrical surface of the grinding wheel, act as cutting tools and remove undesired materials in this operation. The interaction of the workpiece with the cutting tool during chip generation identifies its mechanical characteristics.

Process parameters are often chosen based on the data book or operator expertise. However, the drawback is that productivity suffers as a result. Thus more investigations into the impact of surface grinding parameters on cutting forces and resultant surface roughness are needed in the industry.

The optimization in this study is done using the Taguchi technique. The Taguchi technique was created by Taguchi. He presented a three-step strategy to engineering optimization of a process or product: i. System design, ii. Parameter design and iii. Tolerance designs are the three steps in the design process.

Selvam [8] used the genetic algorithm and the Taguchi approach to conduct trials to improve the machining parameter for face milling in CNC. The trials are carried out with a "zinc coated carbide" tool in a "mild steel" workpiece. The depth of cut, feed rate and spindle rotating speed are the characteristics he examined. The "Vertical CNC face milling machine" is used to carry out these tasks.

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Malay [9] used ANOVA, Taguchi, and the s/n ratio approach to conduct studies to improve machining settings in CNC milling. This experiment's main goal is to achieve a low surface roughness. The experiment is carried out with the use of a "High speed steel" tool in an "Aluminum alloy" workpiece. Speed, feed, and depth of cut are the criteria he examined. In a "vertical CNC milling machine," these processes are carried out.

Akhilesh Chawdhary [10] used Taguchi, S/N ratio to perform an experiment on optimizing machining settings in dry end milling. The major goal of this experiment is to achieve a high-quality surface finish. The experiment is carried out using a carbide tool on a workpiece made of "AL alloy AL6082." The depth of cut, speed, and feed rate are the variables that were investigated. These tests are carried out on a milling machine.

The effects of a workpiece and grinding settings on minimal quantity lubrication (MQL) were explored by Tawakoli et al. [11], and the findings were compared to dry lubrication.

Silva et al.[12–13] used the (MQL) approach to study the impact of grinding settings on the ABNT 4340 steel. Cutting speed, feed rate, cut depth, and cooling method were chosen as variable parameters in this investigation. Other aspects of the process were kept constant. Using the Taguchi approach and experimentally obtained surface roughness (Ra) findings, the above grinding settings were examined and optimized. To test the success of the Taguchi technique, confirmation experiments were carried out and compared with the Taguchi model to verify the model effectiveness.

II. EXPERIMENTAL SETUP AND PROCEDURES

The experiments were conducted on Wellon machinery surface grinding machine model SG40A/1600. The coolant was a mixture of saponification dissolved oil and water. The two components of grinding forces were measured by V-TECH Grinding Tool Dynamometer model 220B.

2.1 Workpiece Material

The workpiece chosen for this study was ASTM A36 mild carbon steel. The mild and hot-rolled steel ASTM A36 is the most widely utilized. It is appropriate for grinding, punching, tapping, drilling, and machining procedures and has good welding qualities.

The specimens were prepared by electric saw machine with dimension 1.5 cm x 6 cm x 10 cm. Figure (1) shows the workpiece configurations.

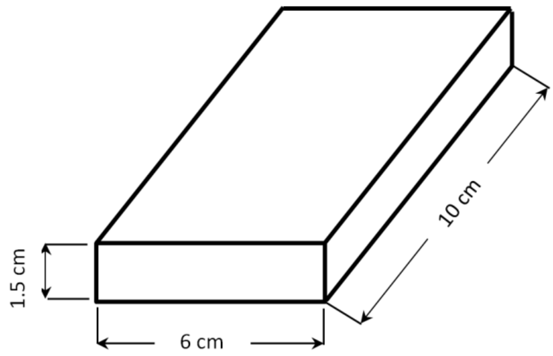

Figure 1: Workpiece configurations

The Chemical composition of ASTM A36 steel which analyzed in STCEI lab is given in table (1).

Table 1: Chemical composition of ASTM A36 steel

Composition	C	Cu	Mn	P	S	Fe
%	0.2	0.18	1.03	0.04	0.05	98

2.2 Grinding wheel Material

In this study two (WA-F46-K6-V40) grinding wheels were used as the tool, in order to change the cutting speed. Those wheels have dimensions of (350x40x127 mm) and (300x40x127 mm).

The characteristics of the grinding wheel are given below:

- Density = 3890 kg/m^3
- Thermal conductivity = 18 W/m.k
- Thermal expansion coefficient = $1x10^{-5}$ K^{-1}
- Specific heat = 880 J/kg.k
- Elastic properties;
- Young's Modulus= 375 GPa and Poisson's ratio= 0.22

2.3 Surface Roughness

Qualitest surface roughness tester model TR200 Surf Test was used to measure the surface roughness resulted from grinding process. Surface Roughness was measured as the arithmetic average, R_a (μm).

2.4 Cutting Forces

The Grinding tool dynamometer can measure simultaneously 3 forces in mutually orthogonal directions, i.e. X, Y and Z. Number of important points such as exact location of forces, the stiffness required, minimum cross sensitivity (i.e., minimization of effect of forces in one direction from the other), ability to withstand extraneous force, etc., have been considered in the design of V-TECH Grinding Tool Dynamometer.

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The dynamometer uses strain gauges to measure the cutting forces. A particular full bridge strain gauge connection have been employed for all orthogonal directions of the three forces inside the dynamometer. The outputs of these strain gauge bridges are available via the 12-pin connector sockets on the sensor body. The picture of the V-TECH Grinding Tool Dynamometer is shown in figure (2) below.

Figure 2: V-TECH Grinding Tool Dynamometer- Model 220B sensor

2.5 Experimental Procedures

Factors and their levels are shown in table (2). Cutting speed, feed rate, depth of cut and the cooling method are adopted as factors (independent variables), which vary during the experiments. The cooling method is considered as a high quantity lubricant (HQL) with flow rate of **0.125 kg/s**and a lower quantity lubricant (LQL) with flow rate of **0.0425 kg/s**. Proper design of experiments is done to make experiments more accurate, less expensive and more efficient. The cooling method factor and the cutting speed factor have two levels. Consequently, they have one degree of freedom (DOF). Each factor of the other two independent variables has three levels. Thus, they have 2 (DOF). The total degree of freedom is the sum of the degree of freedom for each factor. It is clear that the total degree of freedom here is 6.

After specifying the factors and their levels to the columns, trials should be randomized to ensure that human biases are eliminated. For randomization of the experimental runs, a randomization table is used.

After the initial set up, machining parameters are selected according to the requirement. Coolant fluid is pumped into the tank and flushes above the specimen, and then the power is switched on allow the cutting process to start at predefined setting. Before machining each piece, the surface is ensured to be perpendicular on the grinding wheel and the dynamometer reading is equal to zero. Surface roughness is measured with Roughness Taster TR200 with sensitivity of 0.001μm for each sample with a chosen cutoff value of 0.25 mm and four sampling points have been taken. The force is measured with V-TECH Grinding Tool Dynamometer shown in figure (2).

Table 2: Factor levels and factor designation for taguchi design

Machining Parameters	Units	**Factors Levels**		
		1	2	3
Cutting speed	m/s	22	26	-
Cooling method	-	HQL	LQL	-
Feed rate	m/min	2.5	4	6
Depth of cut	mm	0.1	0.15	0.25

III. RESULTS AND DISCUSSIONS

3.1 Response table

The response table for (Ra) is shown in table (3) along with the input factors.

Table 3: Response table

Run	**Cutting Speed**	**Cooling Method**	**Feed Rate**	**Depth of cut**	**Surface Roughness**
	(m/sec)		(m/min)	mm	Ra (μm)
1	26	LQL	2.5	0.1	0.182
2	26	LQL	4	0.15	0.33
3	26	LQL	6	0.25	0.25
4	26	LQL	2.5	0.1	0.193
5	26	LQL	4	0.15	0.303
6	26	LQL	6	0.25	0.335
7	26	LQL	2.5	0.1	0.189

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8	26	LQL	4	0.15	0.304
9	26	LQL	6	0.25	0.322
10	26	HQL	2.5	0.1	0.202
11	26	HQL	4	0.15	0.254
12	26	HQL	6	0.25	0.284
13	26	HQL	2.5	0.15	0.168
14	26	HQL	4	0.25	0.351
15	26	HQL	6	0.1	0.318
16	26	HQL	2.5	0.15	0.163
17	26	HQL	4	0.25	0.311
18	26	HQL	6	0.1	0.33
19	22	LQL	2.5	0.15	0.439
20	22	LQL	4	0.25	0.506
21	22	LQL	6	0.1	0.357
22	22	LQL	2.5	0.15	0.473
23	22	LQL	4	0.25	0.489
24	22	LQL	6	0.1	0.332
25	22	LQL	2.5	0.25	0.531
26	22	LQL	4	0.1	0.448
27	22	LQL	6	0.15	0.632
28	22	HQL	2.5	0.25	0.477
29	22	HQL	4	0.1	0.487
30	22	HQL	6	0.15	0.522
31	22	HQL	2.5	0.25	0.448
32	22	HQL	4	0.1	0.493
33	22	HQL	6	0.15	0.521
34	22	HQL	2.5	0.25	0.492
35	22	HQL	4	0.1	0.499
36	22	HQL	6	0.15	0.517

3.2 Influences on Ra

Analysis of Variance (ANOVA) is used here to test the null hypothesis with respect to the data acquired during the experiments. In this investigation the confidence level was chosen to be **90%**.Therefore P-values less than 0.1 shows that the effect of the relevant factor is significant.

It is clear from table (4) that cutting speed (**P= 0.000**) and the feed rate (**P= 0.072**) has the most significant impact on Ra. Also, the depth of cut (P= 0.15) has moderate significance effect on Ra.

Table 4: Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	1	137.505	122.319	122.319	47.52	**0.000**
Cooling	1	0.000	0.000	0.000	0.00	0.994
Feed	2	17.374	17.374	8.687	3.37	**0.072**
Depth	2	11.349	11.349	5.675	2.20	0.157
Residual Error	11	28.315	28.315	2.574		
Total	17	194.543				

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The signal to noise ratio is used to determine the best condition. The usual procedure for conducting a S/N ratio study is to compute **η** for each treatment group and consider the group that provides the greatest value as the best condition. The case form that is encountered with here is "the-smaller-the-better" static problems.

The S/N ratios for **Ra** can be evaluated as specified in equation (1). The Taguchi method is used to analyze the response which was the result of changing the input machining parameter for smaller is better criteria.

$$SB: \eta = -10 \log[\frac{1}{n}\sum_{i=1}^{n} y_i^2] \quad \text{.......Equ. (1)}$$

Where **η** represents the S/N ratios calculated from observed values, y_i is the empirically observed value of the i^{th} experiment, and n is the number of times the experiment was performed in L-36 OA.

The goal of SNR analysis is to determine a set of parameters where signals are the most prominent. S/N ratios at the factor level are depicted in figure (3) and table (5). The greatest number of **η** denotes the best condition.

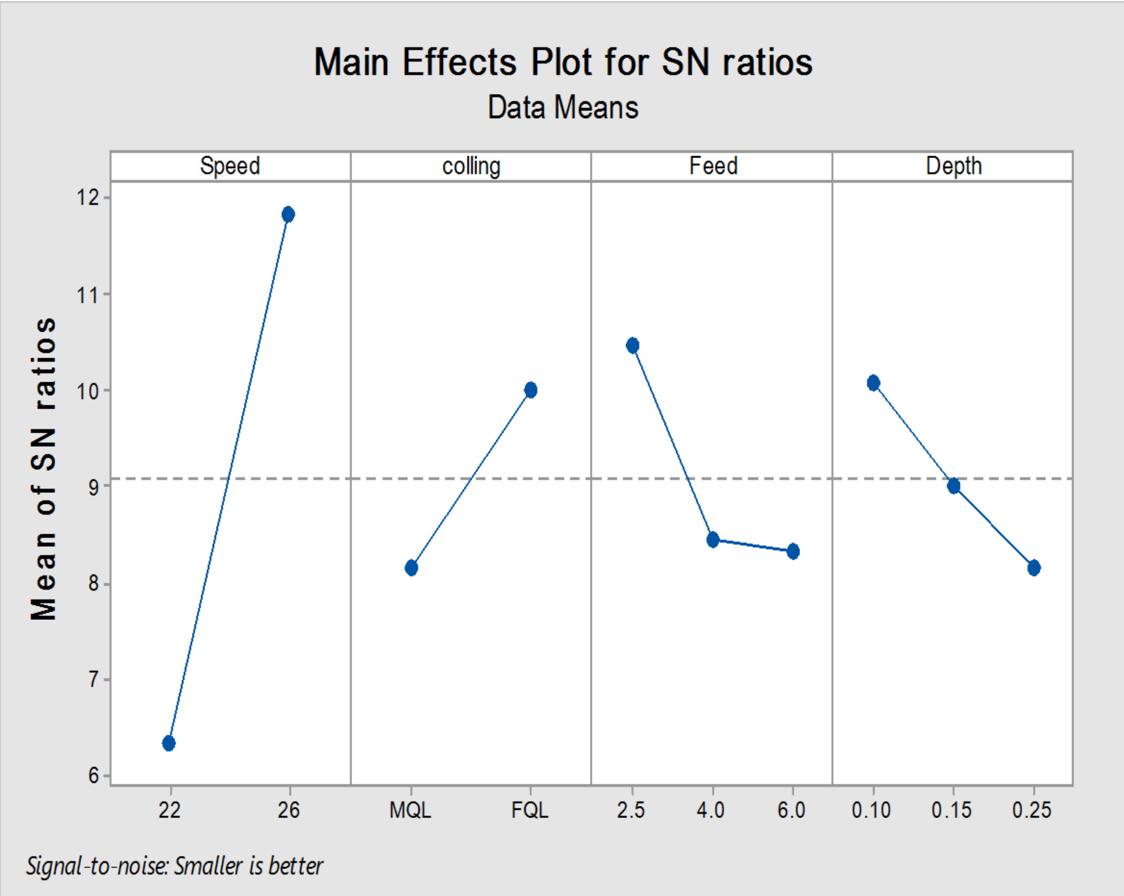

Figure 3: Plot of the S/N ratio for surface roughness

Table 5: Response Table for Signal to Noise Ratios smaller is better

Level	Cutting Speed	Cooling Method	Feed Rate	Depth of Cut
1	6.324	8.170	10.475	10.094
2	11.852	10.007	8.462	9.018
3			8.327	8.153
Delta	5.528	1.837	2.148	1.941
Rank	**1**	**4**	**2**	**3**

Optimal factor levels are obtained from figure (3) and are summarized in table (6).

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Table 6: Optimal factor levels for surface roughness

Level	Optimal level	Optimal amount
Cutting Speed	2	**26**
Feed Rate	1	**2.5**
Depth of Cut	1	**0.1**
Cooling Method	2	**HQL**

The relation between the input variables and the output response (Ra) was investigated using regression analysis. Because variables and responses are believed to be linearly connected, the regression equation is as follows:

$$Y = \beta_0 + \beta_1 x_1 + \cdots + \beta_i x_i + \cdots + \beta_n x_n \quad \text{.......Equ. (2)}$$

Where Y represents the response and β_i represents the i^{th} factor's regresses and signifies residual. The following is the obtained regression equation:

Ra = 1.530 - 0.05381 (Cutting Speed) + 0.01706 (Feed Rate) + 0.385 (Depth of Cut) ……………….… Equ. (3)

Table (7) compares and verifies the results of the regression model with the results of the actual treatment. It turns out that the error between the model and the experimental results is 1.916% for Ra.

Table 7: Verification of the regression model

Run	Factors			Ra		%Ra Error
	Cutting Speed	Feed Rate	Depth of Cut	Exp	Cal	
1	26	3	0.03	0.191	0.1936	1.361%
2	26	5	0.05	0.240	0.2354	1.916%
4	26	2	0.22	0.254	0.2497	1.692%

IV. CONCLUSIONS

The present work has investigated the effect of various machining parameters on the surface roughness of a grounded surface of (ASTM A36) mild carbon steel workpiece using aluminum oxide wheel and had ascertained the effect of four important process parameters i.e., feed rate, cutting speed, cooling method and depth of cut at different test conditions on the surface roughness.

In this investigation, the employment and adjustment of the Taguchi optimization method to improve the surface roughness in the grinding process is elaborated. It is demonstrated that with fewer trails and experiments, the Taguchi methodology provides a systematic and efficient approach. The experimental outcomes acquired from this investigation revealed that the cutting speed and feed rate have the most significant effects on the surface roughness.

The depth of cut has a medium effect on the surface roughness. A change made to any input parameters dramatically changes the quality of the produced surface. The optimal input grinding parameters group for the ASTM A36mild carbon steel involves the cutting speed of **26 m/min**, feed rate of **2.5 m/sec**, and the depth of cut of **0.1 mm** combined with **a high quantity lubricant**.

REFERENCES

[1] Hatem, H. "Study the Effect of Cutting Conditions for turning process on the Machined Surface". *Nahrain Univ. Coll. Eng. J.* 2011, 14, 61–66.

[2] Ashvin, J.; Nanavati, J.I. "Optimization of machining parameters for turning operations based on response surface methodology". *Measurement, 2*013, 46, 1521–1529.

[3] Sarosh, M.; Jahanzaib, M.; Mumtaz, J.; Sarfraz, S. "Investigation of Electric Discharge Machining Parameters to Minimize Surface Roughness". *Pak. J. Sci.* 2016, 68, 315–325.

[4] Charles, S.; Arunachalam, V.P. "Property Analysis and Mathematical modeling of machining properties of Aluminum alloy hybrid composites produced by liquid metallurgy techniques". *Indian J. Eng. Mater. Sci.* 2004, 11, 473–480.

[5] Shin, Y.C.; Coker, S.A. "Surface Roughness Measure by Ultrasonic Sensing for in Process Monitoring". *J. Eng. Ind.* 1995, 117, 439–447. [CrossRef].

[6] G. Taguchi, "Introduction to Quality Engineering", *Asian Productivity Organization*, *Tokyo* 1990.

[7] W. H. Yang, Y. S. Tarng, "Design Optimization of cutting parameters for turning operations based on the

ISSN (online): 2581-3048
Volume 6, Issue 5, pp 124-130, May-2022
https://doi.org/10.47001/IRJIET/2022.605015

Taguchi method", *Journal of Materials Processing Technology*, 84 (1998), 122-129.

[8] Serif çetin1, turgay, Optimization of the machining parameters for the turning of 15-5 ph stainless steels using the taguchi method", *duzce university, institute of science and technology, department of manufacturing engineering, 81620*, duzce, turkey prejemrokopisa – received: 2016- 01-05; sprejem za objavo – accepted for publication: 2016-01-27.

[9] Malay, "Optimization of machining parameters affecting surface roughness of al6082 in dry end milling operation on vmcakhilesh chaudhary", *International research journal of engineering and technology (irjet)* e-issn: 2395- 0056, volume: 04 issue: 08 | aug - 20w1w7.

[10] Akhilesh Chawdhary, "Optimization of process parameters of cnc milling", Malay, volume 3, issue 4 (2016) 59-63, issn 2347 - 3258 *International journal of advance research and innovation*.

[11] T. Tawakoli, M. J. Hadad, M. H. Sadeghi, A. Daneshi, S. Stockert, A. Rasifard, "An experimental investigation of the effects of workpiece and grinding parameters on minimum quantity lubrication-LQL grinding, *International Journal of Machine Tools & Manufacture,* 49 (2009), 924-932.

[12] L. R. Silva, E. C. Bianchi, R. E. Catai, R. Y. Fusse, T. V. Franca, P. R. Aguiar, "Study on the behavior of the minimum quantity lubricant- MQL technique under different lubrication and cooling conditions when grinding ABNT 4340 steel", *J. Braz. Soc. Mech. Sci. Eng.*, 27 (2005) 2, 192-199.

[13] L. R. Silva, E. C. Bianchi, R. Y. Fusse, R. E. Catai, T. V. Franca, P.R. Aguiar, "Analysis of surface integrity for minimum quantity lubricant-MQL in grinding", *Int. J. Mach. Tools Manuf.*, 47 (2007) 2, 412-418.

[14] Mahardika, M., Tsujimoto, T., & Mitsui, K., "A new approach on the determination of ease of machining by EDM processes", *International Journal of Machine Tools and Manufacture,* 48, 746-760, (2008).

[15] Mishra, V.K., Salonitis, K. 2013, "Empirical estimation of grinding specific forces and energy based on a modified Werner grinding model", *Procedia CIRP*, Vol.8: Page 287-292.

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