An Experimental Investigation on Cylindrical Grinding Process Parameters for En 8 Using Regression Analysis

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Abstract **- Cylindrical grinding is one of the important metal cutting processes used extensively in the finishing operations. Metal removal rate and surface finish are the important output responses in the production with respect to quantity and quality. The main objective of this paper is find out set of parameters that minimize the surface roughness and maximize material removal rate for en8 steel. The experiments are conducted on cylindrical grinding machine with full factorial method and surface roughness is measured using surface roughness tester Mitutoyo SJ-210. The test models were developed using full factorial method and regression analysis and tested with the conformation test. The input parameters considered are: cutting fluids, work piece speed, and depth of cut and the responses are surface roughness (Ra) and metal removal rate (MRR). Conformation test gives surface roughness of 0.4246 µm, and material removal rate of 0.0974 gm/sec. test results showed that the use of various coolants reduces surface roughness and increases material removal rate. The results were further validated by conducting confirmation experiments.**

Key Words **- cylindrical grinding, ANOVA, regression analysis, S/N ratios, surface roughness, MRR**

I. INTRODUCTION

A lot of attempts have been made to describe more effectively and adequately the grinding process. this is dissimilar to other machining processes such as turning and milling, as the cutting edges of the grinding wheel don't have uniformity and act differently on the work piece at each grinding. cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. as compared with other machining processes, grinding is costly operation that should be utilized under optimal conditions. although widely used in industry, grinding remains perhaps the least understood of all machining processes. the present paper takes the following input processes parameters namely work piece speed, cutting fluids and depth of cut, the main objective of this paper is to show how our knowledge on grinding process can be utilized to predict the grinding behavior and achieve optimal operating processes parameters and that will minimize surface roughness and maximize metal removal rate when grinding en 8 steel materials. the width of wheel and work piece did not affect surface quality, but a type of wheel was important factor on surface roughness. the grinding machine is used for roughing and finishing flat, cylindrical, and conical surfaces; finishing internal cylinders or bores; forming and sharpening cutting tools; snagging or removing rough projections from castings and stampings; and cleaning, polishing, and buffing surfaces. once strictly a finishing machine, modem production grinding machines are used for complete roughing and finishing of certain classes of work.[01]

M. janardhan, and a.gopala krishna explains that in cylindrical grinding metal removal rate and surface finish are the important responses. they have conducted experiments on CNC cylindrical grinding machine using en8 material (bhn=30-35) and he found that the feed rate played vital role on responses surface roughness and metal removal rate than other process parameters. they have resulted reveals that feed rate, depth of cut are influences predominantly on the output responses metal removal rate (MRR) and surface roughness (Ra) very effectively. [02] Grinding wheel consists of hard abrasive grains called grits, which perform the cutting or material removal, held in the weak bonding matrix. a grinding wheel commonly identified by the type of the abrasive material used. the conventional wheels include aluminum oxide and silicon carbide wheels, while diamond and CBN (cubic boron nitride) wheels fall in the category of super abrasive wheel. [03]

In addition, coolant keeps the chips washed away from the grinding wheel and point of contact, thus permitting free cutting. clear water may be used as a coolant, but various compounds containing alkali are usually added to improve its lubricating quality and prevent rusting of the machine and work piece. an inexpensive coolant often used for all metals, except aluminum, consists of a solution of approximately 1/4 pound of sodium carbonate (sal soda) dissolved in 1 gallon of water. Another good coolant is made by dissolving soluble cutting oil in water. for grinding aluminum and its alloys, a clear water coolant will produce fairly good results. it is known that the cooling and lubrication performance of grinding fluid is the key technical area for the success application of MQL grinding process. various types of fluid like water based al2o3, pure water, dry water, pure oil, water soluble oil, ammonia is applied to grinding process with mql for its excellent property [04]

Jae-seobkwak, sung-bosim, yeong-deugjeong discussed that to analyses the power and surface roughness during the grinding of steel in external grinding. in this study, the response surface method was applied for analyzing the grinding power and the surface roughness in the external cylindrical grinding of the hardened scm440 material by using the grinding parameters, the second-order response surface models for the grinding power and the surface roughness in the external cylindrical grinding were developed. [05] L;ijohnp george, k predicted about the working of cylindrical grinding machine and effect process parameter on surface roughness. it also formulates an empirical relationship between the surface roughness values and the input parameters.[06] Monici used an appropriate methodology of "grinding wheels and coolant" combinations to analyze the quantity of cutting fluid applied in the process and its consequences. based on this analysis, they have investigated a new form of applying cutting fluid aimed at improving the performance of the process. the results revealed that, in every situation, the optimized application of cutting fluid significantly improved the efficiency of the process, particularly the combined use of neat oil and CBN grinding wheel[07]

M. kiyaka, o. cakirb, e. altana have carried out experimental study in dry and wet (%5 emulsion cutting fluid) machining conditions using aisi1050 steel at various work piece speeds and feed at constant wheel speed and grinding depth. they have concluded that to obtain better surface quality in dry grinding should be completed at high work piece speed and low feed. however, in wet grinding, both work piece speed and feed should be kept low for a lower surface roughness[08]

II. MATERIALS AND METHODS

Work Piece Material

The mild steel round bar of EN8 materials is used for this experimental work. Its hardness is 248-302 brinell, max stress is 700-850 n/mm2 , yield stress is 465 n/mm2 min, elongation is 16% min, work piece length is 150mm ,grinding length is 100 mm and diameter is 22mm and its grade is 080M40. Its chemical composition is under given.

Table 3.1: chemical composition of EN8 – 080M40 materials

Carbon	Silicon	Manganese	Phosphorus	Sulphur
0.44	0.26	0.86	0.031	0.021

Machining Process

The grinding tests were performed on General purpose grinding machine and Aluminum oxide White grinding wheel. After turning, work pieces are grinded in cylindrical grinding machine The various process parameters of a cylindrical grinding machine include depth of cut, material hardness, work piece speed, grinding wheel grain size, and grinding wheel speed. The present paper takes the following input processes parameters namely cutting fluids, work piece speed and depth of cut. The other parameters are kept constant. The experiments were conducted as per the full factorial method.

Table: 3.2 Factors with values of different levels

Factors	Level 1	Level 2	Level 3
Cutting Fluids	Water Soluble Oil	Pure Oil	Pure Water
Work Piece Speed(rpm)	60	75	120
Depth Of Cut(µm)	300	400	500

III. DESIGN OF EXPERIMENT AND MEASUREMENT

Plan of Experiment

The design of experiment was planed using full factorial method. By this method 27 experiments is performed on grinding machine

Table: 3.3 Design of Experiment for Grinding of EN8

Sr. No	Cutting Fluids	Work Piece Speed (Rpm)	Depth Of Cut (µm)
1	Water Soluble Oil	60	300
2	Water Soluble Oil	60	400
3	Water Soluble Oil	60	500
4	Water Soluble Oil	75	300
5	Water Soluble Oil	75	400
6	Water Soluble Oil	75	500
7	Water Soluble Oil	120	300
8	Water Soluble Oil	120	400
9	Water Soluble Oil	120	500
10	Pure Oil	60	300
11	Pure Oil	60	400
12	Pure Oil	60	500
13	Pure Oil	75	300
14	Pure Oil	75	400
15	Pure Oil	75	500
16	Pure Oil	120	300
17	Pure Oil	120	400
18	Pure Oil	120	500
19	Pure Water	60	300
20	Pure Water	60	400

21	Pure Water	60	500
22	Pure Water	75	300
23	Pure Water	75	400
24	Pure Water	75	500
25	Pure Water	120	300
26	Pure Water	120	400
27	Pure Water	120	500

Surface Roughness and MRR Measurements

Surface roughness for various combinations of parameters was measured using surface roughness tester (sj-210) the MRR is calculated by taking the difference between weights of work materials before and after grinding and it is divided by the machining time.

Material removal rate is measure with the help of theoretical equation which contain weight before machining, weight after machining and machining time.

MRR=(weight before machining-weight after machining) ÷Machining time

Table 3.4 Result of surface roughness, material removal rate obtained From Experimental work

Experiment No.	Surface Roughness (µm)	Material Removal Rate (gm/sec)
1	0.447	0.0797
2	0.4246	0.0892
3	0.4703	0.0858
4	0.493	0.0681
5	0.4583	0.0904
6	0.5046	0.0851
7	0.4516	0.0725
8	0.4386	0.0825
9	0.4233	0.0973
10	0.4886	0.0522
11	0.5136	0.0609
12	0.507	0.0613
13	0.5273	0.0628
14	0.465	0.093
15	0.4556	0.0873
16	0.4436	0.0512
17	0.4676	0.085
18	0.4836	0.0745
19	0.8026	0.05
20	0.8803	0.0666
21	0.6376	0.0945
22	0.7413	0.0569
23	0.732	0.0939
24	0.6543	0.0705
25	0.7183	0.0705
26	0.6863	0.0784
27	0.6343	0.125

IV. OPTIMIZATION USING REGRESSION ANALYSIS

Here we use regression analysis for a optimization of cutting fluids, work piece speed and depth of cut. For the regression analysis here full factorial method is used for design of input parameters.

The cutting fluids, work piece speed and depth of cut were considered in the development of mathematical models for the surface roughness and metal removal rate. The correlation between factors (cutting fluids, work piece speed and depth of cut) and surface roughness or metal removal rate on the EN8 materials were obtained by multiple linear regressions.

The standard commercial statistical software package MINITAB was used to derive the models of the form:

The S/N ratio used for this type response is given by:

S/N = -10*log (mean square deviation)

$$\frac{S}{N} = -10log(\frac{1}{n}\Sigma \quad 1/\,y2\,) \quad (1) \quad \text{here } (n=1)$$

The S/N value Approach for surface roughness the smaller - the better and for MRR the larger – the better

Table 4.1 S/N ratio values for surface roughness and MRR

Exp. No.	S/N Ratio for surface roughness(dB)	S/N Ratio for MRR(dB)
1	-6.9938	-21.9708
2	-3.7202	-20.9927
3	-6.5525	-26.7826
4	-6.143	-23.337
5	-6.777	-20.8766
6	-5.941	-21.4014
7	-6.9049	-24.0823
8	-7.1586	-21.6709
9	-7.467	-20.2377
10	-6.2214	-22.8292
11	-5.7887	-21.841
12	-5.9006	-20.7905
13	-5.5595	-24.0408
14	-4.6509	-20.6303
15	-6.8283	-21.1797
16	-7.0601	-17.6413
17	-6.6025	-21.416
18	-6.3102	-22.5568
19	-1.91	-26.0205
20	-0.5536	-23.5305
21	-3.909	-20.4913
22	-2.6001	-24.8977
23	-2.7097	-20.5466
24	-3.6844	-23.0362
25	-2.8738	-23.0362
26	-3.2669	-22.1136
27	-3.9541	-18.0617

Table 4.2 S/N ratio values for surface roughness by factor level (smaller is better)

Level	Cutting Fluids	Work piece speed	Depth of Cut
1	-6.4064[a]	-4.6164	-5.1407
2	-6.1024	-4.9882	-4.9446
3	-2.8290	-5.7331[a]	-5.6163[a]
Delta	3.5774	1.6282	0.6717
Rank	1	2	3

where [a] indicate Optimum level

Regardless of the category of the performance characteristics, a smaller S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the smallest S/N value. Based on the analysis of the S/N ratio, the optimal machining performance for the surface roughness was obtained at water soluble oil (level 1), 120 rpm work piece speed (level 3), 500 µm depth of cut (level 3).

Table 4.3 S/N ratio values for surface roughness by factor level (larger is better)

Level	Cutting Fluids	Work piece speed	Depth of Cut
1	-21.623[a]	-22.8054	-23.095
2	-23.316	-22.2162	-21.622
3	-22.415	-21.2018[a]	-21.615[a]
Delta	1.693	1.6036	1.48
Rank	1	2	3

where [a] indicate Optimum value

Regardless of the category of the performance characteristics, a smaller S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the smallest S/N value. Based on the analysis of the S/N ratio, the optimal machining performance for the MRR was obtained at water soluble oil (level 1), 120 rpm work piece speed (level 3), 500 µm depth of cut (level 3).

V. RESULT AND DISCUSSION

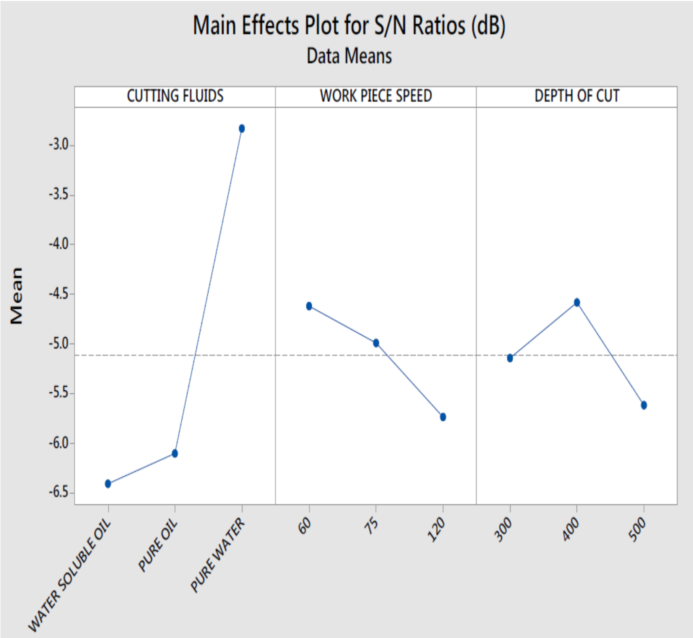

Fig. 5.1 main effect plot of S/N ratios for surface roughness

Table 4.2 and fig. 5.1 predict the factor effect on surface roughness. the lower signal to noise ratio, the more favorable effect of the input parameters on output parameters. the optimum value for surface roughness (minimum) are at a water soluble oil as a cutting fluid, 120 rpm work piece speed, 500 µm depth of cut.

From the table it can be seen that most influencing parameter for surface roughness of EN8 is water soluble oil, cutting fluids followed by depth of cut and work piece speed.

Regression equation for surface roughness,

Surface roughness = 0.695 - 0.00077 work piece speed - 0.000190 depth of cut. (2)

Table 4.3 and fig. 5.2 predict the factor effect on MRR. the higher signal to noise ratio, the more favorable effect of the input parameters on output parameters. the optimum value for MRR (maximum) are at a water soluble oil as a cutting fluid, 120 rpm work piece speed, 500 µm depth of cut.

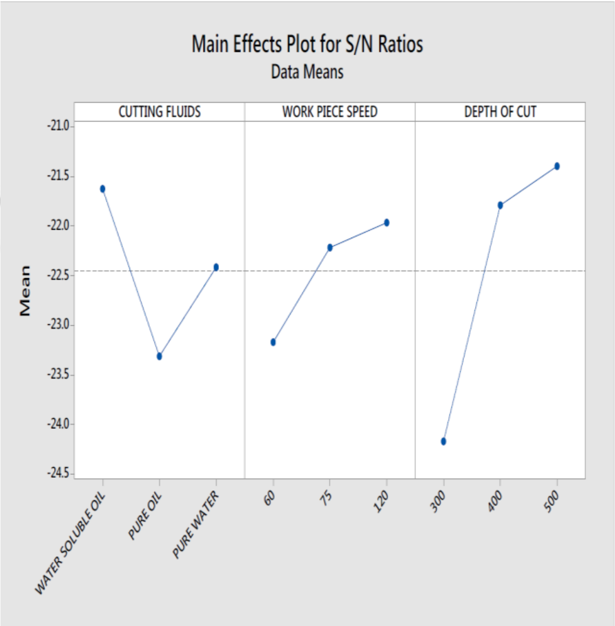

Fig. 5.2 main effect plot of S/N ratios for MRR

From the table it can be seen that most influencing parameter for surface roughness of EN8 is water soluble oil, cutting fluids followed by depth of cut and work piece speed Regression Equation for MRR

MRR = 0.0158 + 0.000154 work piece speed + 0.000121 depth of cut. (3)

Table 5.1 Optimum Set of Input Parameters

Srno	Output parameters	Cutting fluid	Work piece speed(rpm)	Depth of cut (µm)
1.	Surface Roughness	Water soluble oil	120	500
2.	MRR	Water soluble oil	120	500

VI. CONFORMATION TEST

The experimental conformation is the final setup in verifying the result drawn based on full factorial method. The optimum set of parameters and selected number of experiment are run under the specified condition. The average of the result from the conformation test is compared with the predicted average based on the parameters and levels. in this study conformation result for EN8 is as follows:

Table 6.1 conformation of experiment.

surface roughness	MRR
0.4246 µm	0.0974 gm/sec

VII. CONCLUSION

This paper has discussed an application of regression analysis for investigation of process parameters on the surface roughness and MRR in the grinding of EN8 materials. in the grinding parameters were taking into consideration for industrial requirements.

From the analysis of result of the cylindrical grinding process using the signal-to-noise (s/n) ratio approach, regression analysis approach, the following result can be concluded from the present study.

- The cutting fluid (water soluble oil) was most influencing factor for EN8 materials followed by work piece speed and depth of cut. So to achieve a optimum value of surface roughness and MRR for EN8 steel, employ water soluble oil as a cutting fluid, highest work piece speed 120 rpm and high depth of cut 500 µm
- In this study the analysis of the conformation test for surface roughness and MRR shown that full factorial method can successfully verify the optimum cutting parameters.
- Higher work piece speed and higher the depth of cut improves surface finish when grinding in water soluble oil. With emulsion coolant, better surface finish is obtained at higher work piece speed and higher depth of cut with manual feed.
- Water soluble oil contain higher flow ability with a medium viscosity, when pure oil gives poor flow ability with a high viscosity and pure water gives higher flow ability with poor viscosity. this study shows that, due to high flow ability and medium viscosity gives maximum value of surface roughness.
- As the work piece speed increases, the rubbing of the abrasive grain also increases so the MRR also increased. same as the depth of cut increases, the chip thickness also increases so MRR increased.
- Water soluble oil gives better surface roughness than pure water due to oil smoothened cutting action. Pure oil gives higher surface roughness than water soluble oil because it only contains high viscosity oil cutting action.
- As the work piece speed increases the rubbing of the abrasive grain also increased and it leads to reduced surface roughness. Depth of cut increases from lowest to highest level, surface roughness was reduced.
- Grain size has an effect on the obtained results, fine grain finish are better.

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