Optimization of Cylindrical Grinding of Alloy Steel using desirability function approach

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Abstract - *The analysis of variance (ANOVA) results for a single optimization corroborate the previous finding by showing that the depth of cut has the greatest influence (92.06%), followed by the cutting speed (4.65%) and feed rate (0.94%) with the least influence on the MRR values. The calculation of the grey relational grade in equation (7) results in a value of 0.4413, indicating that the ideal collection of input control parameters is A2B3C1. Table 5.9 displays the results of the confirmation experiment for the response parameters. It should be noted that the experimental values of Cutting Speed (VC) in rpm, Depth of Cut mm, and Feed Rate mm/rev are all greatly improved by GRA.*

Key Words: cylindrical grinding, material removal rate, and desirability factor. En9 alloy steel, single optimization

1. INTRODUCTION

1.1 How Does Grinding Work and What Is It?

In modern production, machining that uses high-speed abrasive wheels, pads, and belts are referred to as "grinding." Grinding wheels come in a wide range of diameters, contours, and abrasive kinds. The following chapters will go through the most common wheel and abrasive kinds. Grinding is one abrasive machining technique. Abrasive machining methods include polishing, lapping, honing, and other sophisticated finishing treatments. There are several aspects of grinding technology that overlap with this broad range of tasks. The only factor that distinguishes grinding from other processes is their kinematics, some of which, like lapping, need quite little frictional force. Rarely, the abrasive process can be aided by chemical or electrochemical principles, extending the grinding process.

The concepts and methods given in this book can be applied to other aspects of super finishing, even though the mechanical friction process is the primary focus of the majority of the techniques and principles discussed. Grinding is a process used to remove material and increase surface area in order to condition and polish metal and other materials. Ten times more accuracy may be achieved through surface finishing and grinding than through milling or even turning. A substantial abrasive product—typically a rotating wheel—makes contact with the work surface when grinding. [3]

This chapter explores the role that grinding plays in modern production, including its origins, how it works, and how it relates to strategy. As top concerns, cost, quality, and manufacturing speed are cited. ability to learn from machines Low surface roughness, good surface integrity, and high precision with very hard materials like steel and ceramics are distinctive characteristics. Current trends include accelerating production rates, using tougher and more advanced abrasives, and developing machines and control systems with ultra-precise capabilities. The fundamental mechanisms and components of grinding systems are described. The main objective and content of the book are described in order to demonstrate its structure. Other relevant texts are referenced.

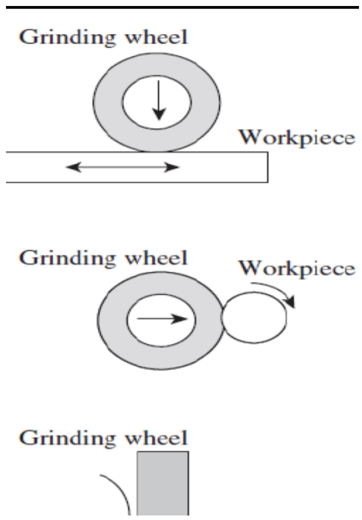


Figure 1.1.Four fundamental grinding techniques are shown in there are four types of grinding: face surface grinding, face cylindrical grinding, and peripheral cylindrical grinding.

1.4 Element Specifications

The following information is included in a system specification.

Work piece material: Form, stiffness, hardness, and chemical and thermal characteristics.

Type, control system, precision, rigidity, temperature stability, and vibrations of grinding machines

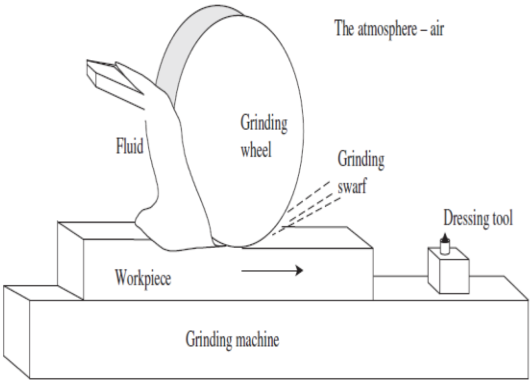


Figure 1.2 shows external center less grinding, external angle grinding, and internal cylindrical grinding. [17]

The movements and geometry that control how the grinding wheel makes contact with the work piece are known as kinematics. The speeds and feeds of the wheel and the work pieces.

• The features of grinding wheels in terms of abrasive, particle size, bond, structure, hardness, speed, stiffness, and chemical composition.

• Dressing circumstances: the kind of tool, feeds and speeds, cooling, lubrication, and maintenance.

• The flow rate, velocity, pressure, physical, chemical, and thermal characteristics of the grinding fluid.

Temperature, humidity, and the impact of the atmosphere on the environment.

• Risks to the public and machine operators' health and safety.

• Waste management.

• Costs.

The Variety of Grinding Methods and References

The full spectrum of grinding operations, which includes single-sided or double-sided face grinding of numerous components placed on a planar surface, is very broad in actuality. The range also contains operations for creating profiles and copying profiles. Grinding spiral flutes, screw threads, spur gears, and helical gears employing techniques akin to gear cutting, shaping, planning, and robbing with cutting tools are all examples of profiling operations. Other techniques can be used to grind campmates, rotary cams, and ball joints. [17]

2. Objective of work:

The goal of this work is to identify the machining parameters in an external cylindrical grinding operation that should be optimized on MRR using the Taguchi technique, response surface analysis, and the GREY connection analysis approach. The three characteristics known as "cutting speed," "depth of cut," and "feed rate" are thought of as the ideal cutting parameters. The precise objectives are listed below. a) To practice design of experiments (DOE) using the cylindrical grinding method (CGP). b) To determine the ideal cutting conditions for raising MRR.

3. Methodology:

DESIGN OF EXPERIMENT: Experiment design is a method created to comprehend the behavior of a mechanical system. Data are accumulating from the variable set sets, and they can be used to qualitatively explain the current situation. Therefore, it is commonly recognized that the goal of any research is to construct an experiment with a minimal number of variables and use this experiment to gather as many data as feasible. Every experiment focuses on the majority of the variables that can have a direct impact on the outcomes. Quantities that have a significant impact on the results of studies can be used to detect these types of factors. One of the most crucial ideas in science is theories, which are used to guide further experiments.

Alloy steel EN6 is chosen as the work piece material in the study presented in [1]

Table 3.1 L27 orthogonal array and results.

Exp. no	Process parameter		Response parameter	
	Cutting speed (rpm)	Depth of cut (mm)	Feed rate (mm/rev)	Material remova rate (g/min)
1	1700	0.02	0.04	1.242
2	1700	0.02	0.04	1.268
3	1700	0.02	0.04	1.204
4	1700	0.04	0.06	1.603
5	1700	0.04	0.06	1.601
6	1700	0.04	0.06	1.719
7	1700	0.06	0.08	2.317
8	1700	0.06	0.08	2.429
9	1700	0.06	0.08	2.430
10	1900	0.02	0.06	1.400
11	1900	0.02	0.06	1.520
12	1900	0.02	0.06	1.768
13	1900	0.04	0.08	1.872
14	1900	0.04	0.08	1.875
15	1900	0.04	0.08	1.941
16	1900	0.06	0.04	2.675
17	1900	0.06	0.04	2.560
18	1900	0.06	0.04	2.510
19	2200	0.02	0.08	1.392
20	2200	0.02	0.08	1.457
21	2200	0.02	0.08	1.468
22	2200	0.04	0.04	1.567
23	2200	0.04	0.04	1.600
24	2200	0.04	0.04	1.771
25	2200	0.06	0.06	2.520
26	2200	0.06	0.06	2.601
27	2200	0.06	0.06	2.643

Parameter	Factor	Level1	Level2	Level3
Cutting Speed(Vc) in rpm	A	1700	1900	2200
Depth of cut mm	B	0.02	0.04	0.06
Feed Rate mm/rev	C	0.04	0.06	0.08

Table 3.2 Control Parameters and their levels [1]

The number of components and the levels chosen for the sets of variables determine how many duplicates are present in the experiment; as the number of experiments increases, so will the number of replicates. Different methods, such as the Taguchi Method, Response Surface Method, Mixture Design, and Full Factorial Method, are employed in the design of experiments. Each experiment has its own significance, and the ideal approach depends on the circumstances or the different types and weights of the many components.

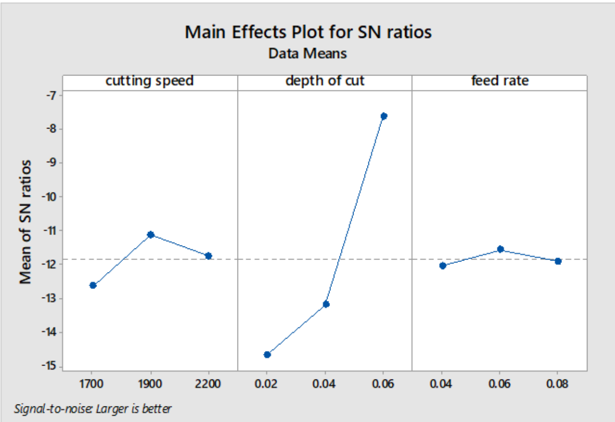


Fig 3.1 Main Effects Plot for SN ratios of MRR

Table 3.2 Response Table for Signal to Noise Ratios Larger is better

Level	Cutting Speed	DOC	Feed Rate
1	4.568	2.920	4.790
2	5.846	4.711	5.433
3	5.233	8.017	5.425
Delta	1.278	5.097	0.643
Rank	2	1	3

Because MRR is a larger-is-better kind of quality characteristic, the major effect plot (Figure 3.1) shows that the second level of cutting speed (A2), first level of depth of cut (B1), and third level of feed (C3) offer the highest MRR value. Relatively slightly, the MRR increases along with the feed rate and cutting speed. The MRR, on the other hand, increases considerably if the depth of incision is increased by 0.02 mm.

Table 3.2 Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value	
Cutting Speed	2	0.29614	4.65%	0.29614	0.14807	19.75	0.000	Significant
DOC	2	5.86121	92.06%	5.86121	2.93060	390.81	0.000	Significant
Feed Rate	2	0.05958	0.94%	0.05958	0.02979	3.97	0.035	
Error	20	0.14997	2.36%	0.14997	0.00750			
Lack-of-Fit	2	0.00736	0.12%	0.00736	0.00368	0.46	0.636	
Pure Error	18	0.14261	2.24%	0.14261	0.00792			
Total	26	6.36690	100.00%					

Model Summary: Finally the regression equation is shown give the exact model equation or it will show the relationship between the input and the output variables.

Table 3.3 Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)
0.0865951	97.64%	96.94%	0.273328	95.71%

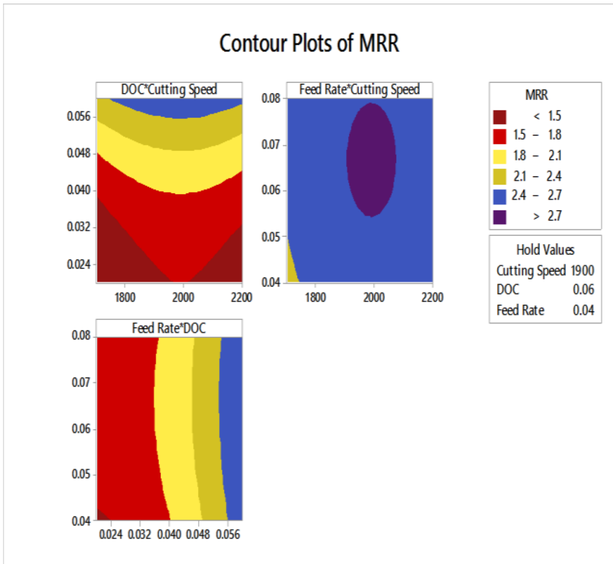
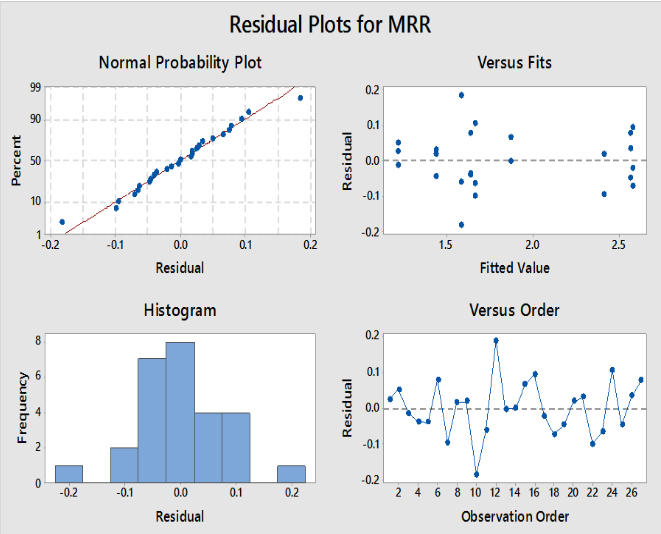


Fig 3.1; Contour plot of MRR

The Effect of the machining parameters (cutting speed, feed, and depth of cut) on the response variables MRR has been predicted. It can be seen from Fig. 3.1, TheMRR tends to increase significantly with increase in feed rate and depth of cut for any value of grit size.



The residual plot for the Material Remover Rate is displayed above. The first graph in this graph is the normal probability graph, in which all the points are located along the normal probability line. This indicates that the data are well fitted for the observation and that there must be a significant correlation between the input and the output variables The second graph is a histogram plot in which the greatest value is plotted at 0, indicating that the majority of the data were either zero or that there is no difference between the residual probability graph and the normal probability graph. The residual's deflection is displayed as the number of observations in the final graph. The final graph displays the deflection in the residual with respect to the number of observations. The maximum data in the histogram plot are on 0, which also means there isn't a lot of space between the data and the normal probability line.

Numerical optimization

The purpose of this research is to find the best parametric settings to achieve maximum Material Removal Rate of grinding process at the same time, which is ideal for good grinding efficiency. The desirability analysis is used to determine the best parametric setting to obtain the absolute Material Removal Rate of the grinding process. The grinding process is optimized using the Minitab18 program. The common steps and procedures that are followed in the Minitab software are described in detail here. The results of multi-objective optimization for Material Removal Rate are shown in fig. 4.1. Optimal Material Removal Rate 2.816(Gm./Min) has been obtained at(a) Cutting Speed(V_C) in rpm A2 1900 rpm (b) Depth of cut (mm), B30.06 mm. (c) Feed Rate 0.04 (mm/rev)C1 The mixed desirability factor D has a value of 0.93650.

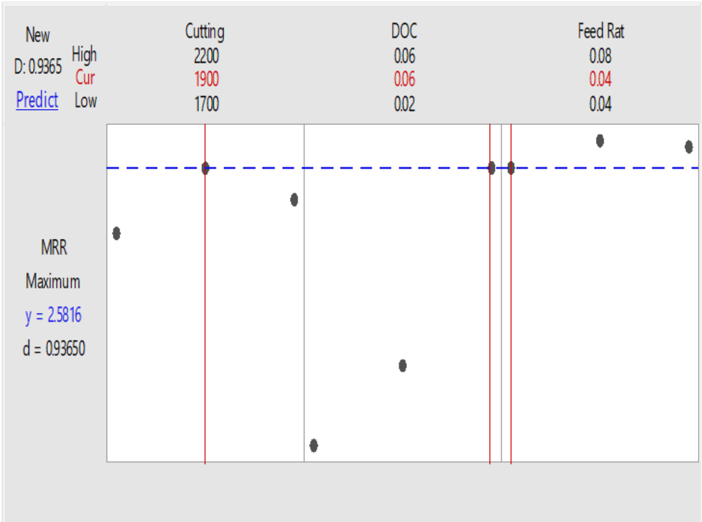


Fig. 4.1 Optimization results of Material Removal Rate by RSM

4.2 Confirmation test

The obtained optimization techniques were confirmed using validation studies. Table 4.1 shows the results of confirmatory tests performed under ideal conditions. It is seen from the table that the error in terms of percentage between the estimated and experimental results is very small and is less than 1%. This indicates for single optimization, for cylindrical grinding, there is significant improvement with the experimental alloy steel EN9.Parameters. Three fresh experiments are conducted for confirmation of models Eqs. (3) And (4), with achieved optimal values of Material Removal Rate. The average of measured values for Optimal Material Removal Rate 2.816 (Gm./Min) has been obtained at(a) Cutting Speed(V_C) in rpm A2 1900 rpm (b) Depth of cut (mm), B3 0.06 mm. (c) Feed Rate 0.04 (mm/rev) C1. The accuracy of the models is analyzed on the basis percentage error. . Since the error is less than10%, it is evidently proved that there is a good agreement between experimental and predicted values [38].Finally, within experimental constraints, an attempt was made to estimate the optimal cylindrical machining position to provide the best desired results.

Table 4.1 Multi-objective optimization results

Optimal Control Parameters	Level	Optimal Level	Experimental	Predicted (RSM)	Error (%)
Cutting Speed(Vc) in rpm	A	A_2 B_3 C_1	2.675	2.5816	1.3
Depth of cut mm	B				
Feed Rate mm/rev	C				

4. The studies led to the following conclusions:

1. The Taguchi orthogonal array has been utilized successfully to determine the ideal level of process parameter setting.

2. Because MRR is a larger-is-better type of quality characteristic, the main effect plot (Figure 3.1) demonstrates that the third level of feed (C3), the first level of depth of cut (B1), and the second level of cutting speed (A2) provide the highest values of MRR between the input and output variables. Consequently, there is a significant correlation between the input and output variables.

3. For a single optimization, the analysis of variance (ANOVA) results based on the estimated MRR values are shown in Table 3.3. These results demonstrate that the depth of cut has the highest contribution (92.06%), followed by the minimum influence from cutting speed (4.65%) and feed rate (0.94%), in determining the MRR values, thereby validating the conclusion reached above.

4. R-sq: In order to anticipate a good agreement between the input and output values, the R-sq value must be over 40%, according to the research technique. The R-sq value is 97.64% in the table below, which illustrates the good agreement between the input and output variables. As a result, there is a significant correlation between the input and output variables.

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