

Experimental Evaluation of Grinding Process Parameters on Surface Finish

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ABSTRACT

Amongst the most important finishing processes employed within the industry to obtain a high-quality surface and good dimensional accuracy, grinding is one such process. Some of the process parameters that influence the quality of the resulting surface after grinding include wheel speed, feed rate, depth of cut, and coolant feeding. In this study, an experiment has been conducted on the parameters of the grinding process to determine their effects on the quality of the surface finish attained through surface grinding operations. A surface grinding machine was used to machine specimens made of mild steel under various process parameters combinations. The results indicate that the feed rate plays an important role in influencing surface roughness variations, while the wheel speed and depth of cut play an equally important role in affecting surface finish. The machining performance and surface finish can be improved using the new grinding conditions.

Keywords: Grinding, Surface Finish, Surface Roughness, Grinding Parameters, Feed Rate, Wheel Speed, Depth of Cut.

1. Introduction

One of the very important abrasive processes that are widely adopted by the current day manufacturing industries in order to attain high geometrical tolerances, excellent surface finish, and precision of dimensioning is grinding. This process is mostly utilized as a finishing operation after regular machining operations like drilling, turning, milling, and shaping. Material removal from the workpiece surfaces in grinding takes place due to the movement of abrasives fixed onto the surface of the rotating grinding wheel. This method has been considered a vital operation in various fields including the automobile industry, aerospace industry, tool industry, bearing industry, and precision engineering industry [1]. There has been an increasing demand for better-performing engineering products recently. There is a close connection between the quality and operational life of engineering parts and surface treatment. Such factors as friction, abrasion resistance, lubricating characteristics, corrosion resistance, fatigue life, and dimensional stability of mechanical parts largely depend on surface roughness. Low surface quality can result in increased wear, initiation of cracks, and shortened service life. Therefore, the possibility of higher surface quality and increased reliability of engineering parts depends on optimal grinding conditions [2]. A number of abrasive particles come into contact with the workpiece surface simultaneously during grinding. Each abrasive particle acts like a miniature cutting tool, shaving off pieces of the part being ground. There are various factors which affect the efficiency of grinding operation such as wheel speed, rate of feed, depth of cut, wheel material, grain size, coolant use, and dressing among others. Some of the significant factors which affect the grinding surface and efficiency include wheel speed, feed rate, and depth of cut [3]. The wheel speed is an essential factor which affects forces of cutting, temperatures during grinding, and chip formation. In many cases, wheel speed is high since smaller thicknesses of chip undeformed lead to improved surface finish. Excessive wheel speeds, however, can lead to problems in relation to wheel wear and overheating. In addition, feed rate is another factor which significantly impacts on the surface finish. While increasing feed rate leads to the faster removal of material, it can make chips thick and cause vibrations in the surfaces. In the same way, the heat production and grinding force depend on the depth of cut. Increased wheel loading, surface defects, and grinding temperature affect the surface condition due to deep cuts [4]. Surface grinding is widely used for obtaining flat surfaces of soft and hardened materials. The correct choice of grinding parameters plays an important role in industry for increasing productivity and maintaining proper surface conditions. The wheel wear, residual stress, chattering, grinding burn, and dimensional errors are possible due to incorrect grinding parameters. Thus, achieving better machining operations and cost reduction require experimental

analysis and grinding parameter optimization [5]. The problem of grinding parameter optimization is widely researched among scientists around the world using various methods of analysis. The influence of grinding factors on surface roughness and the characteristics of material removal have been analyzed through various approaches including the use of Taguchi optimization, ANOVA, RSM, ANN, and GA approaches [6]. According to the results obtained from these studies, the proper selection of grinding factors has a significant role to play in improving surface quality while reducing defects in machining. This study focuses on the experimental evaluation of the influence of grinding factors on the surface finish obtained by surface grinding. Wheel speed, feed rate, and depth of cut have been changed while grinding mild steel work pieces. Surface roughness measurement was conducted in order to find out the influence of these factors on grinding efficiency. Results obtained from experiments conducted in this research will help identify the ideal grinding parameters for obtaining good surface finish.

Table 1: Major Grinding Parameters and Their Effects

Grinding Parameter	Influence on Grinding Performance
Wheel Speed	Improves surface finish and reduces chip thickness
Feed Rate	Higher feed increases roughness and vibration
Depth of Cut	Larger depth increases force and temperature
Abrasive Grain Size	Finer grains produce smoother surfaces
Coolant Flow Rate	Reduces thermal damage and improves finish
Dressing Condition	Maintains wheel sharpness and cutting efficiency

Table 2: Industrial Applications of Grinding

Industry	Grinding Application
Automotive Industry	Engine shafts, gears, bearings
Aerospace Industry	Turbine blades, aircraft components
Tool Manufacturing	Cutting tools and dies
Biomedical Industry	Surgical implants and instruments
Precision Engineering	High-accuracy machine components

2. Materials

Mild steel was selected for the experimentation due to its extensive use in manufacturing industries, ease of machining, decent hardness level, and low cost. Mild steel is commonly used in parts used in industry, shafts, gears, machine frame parts, and automobile parts that require accurate dimensioning and surface finish. In surface grinding experiments, rectangular samples of size 100 mm × 50 mm × 10 mm were fabricated. In order to ensure effective grinding results and reliable values for surface roughness, the samples were properly cleaned in order to remove any surface contamination, rust, or dust. The grinding wheel in this experiment was an aluminum oxide wheel with vitrified bond. Due to high cutting efficiency, high wear resistance, and excellent thermal stability, aluminum oxide wheels have become common when grinding ferrous work pieces. During this experiment, a wheel diameter of 250 mm, a wheel width of 25 mm, and a grain size of 46 mm was used. Prior to conducting any experiments, dressing of the wheel was carried out in order to maintain sharpness and improve grinding efficiency. While performing the grinding process, coolant fluid (water soluble) was used to cool down the process. This helped improve the efficiency of lubrication, reduced the temperature of the process, reduced thermal effects, and provided an enhanced finish to the process.

Table 2: Chemical Composition of Mild Steel

Element	Percentage (%)
Carbon	0.18
Silicon	0.15
Manganese	0.70

Sulfur	0.04
Phosphorus	0.04
Iron	Balance

Table 3: Grinding Wheel Specifications

Parameter	Specification
Abrasive Material	Aluminum Oxide
Wheel Diameter	250 mm
Wheel Width	25 mm
Grain Size	46
Bond Type	Vitrified
Coolant Type	Water Soluble Oil

Table 4: Properties of Mild Steel

Property	Value
Density	7.85 g/cm ³
Hardness	120 HB
Tensile Strength	440 MPa
Yield Strength	370 MPa
Thermal Conductivity	50 W/mK
Melting Point	1425°C

3. Experiment Details

An experiment was designed to measure the influence of grinding parameters on surface roughness in a horizontal spindle surface grinding machine. The material used for grinding was mild steel sample sized 100 mm x 50 mm x 10 mm. In order to maintain uniformity during the experiment, all samples underwent thorough cleaning as well as machining of their surfaces prior to grinding. In order to assure effective cutting action and good grinding results, the grinding wheel was properly prepared for each experiment. Three key grinding parameters such as wheel speed, feed rate, and depth of cut were varied during the experiments. For the purposes of the study, values of wheel speed equaling 1200 rpm, 1500 rpm, and 1800 rpm were selected. The depth of cut of 0.01 mm, 0.02 mm, and 0.03 mm was maintained, whereas feeds of 100 mm/min, 150 mm/min, and 200 mm/min were utilized. While carrying out grinding processes, water-soluble coolant was continuously applied to decrease the heat production during the process and improve surface finish.

A surface roughness measuring instrument was used to determine the surface roughness of the workpiece. Arithmetic average roughness (Ra) was recorded for analyzing purposes. The mean value was considered due to several measurements taken from various spots on the ground surface. The effect of grinding parameters on surface roughness was determined based on experimental results.

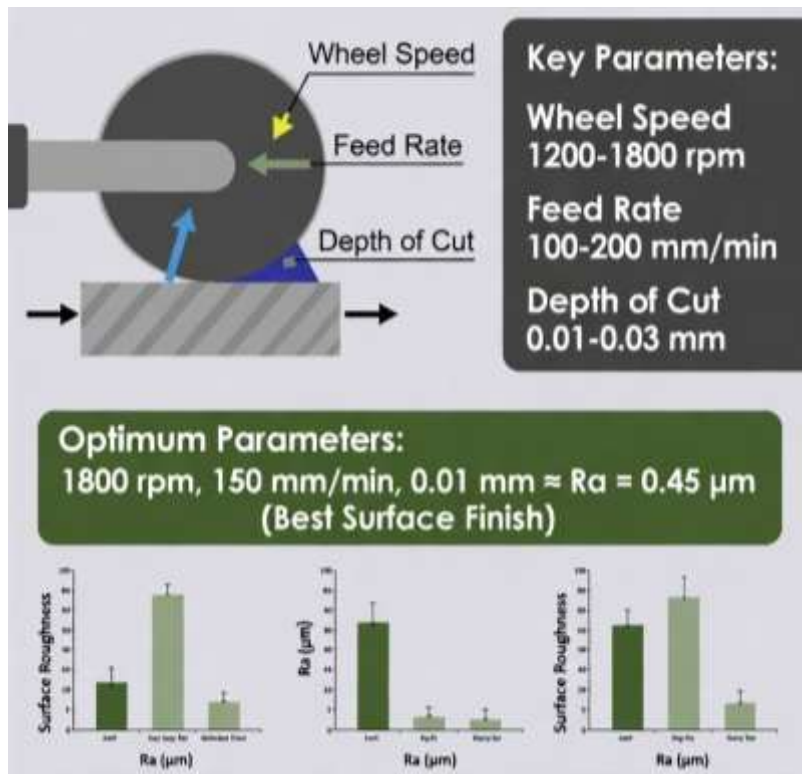


Fig 1: Working Parameters

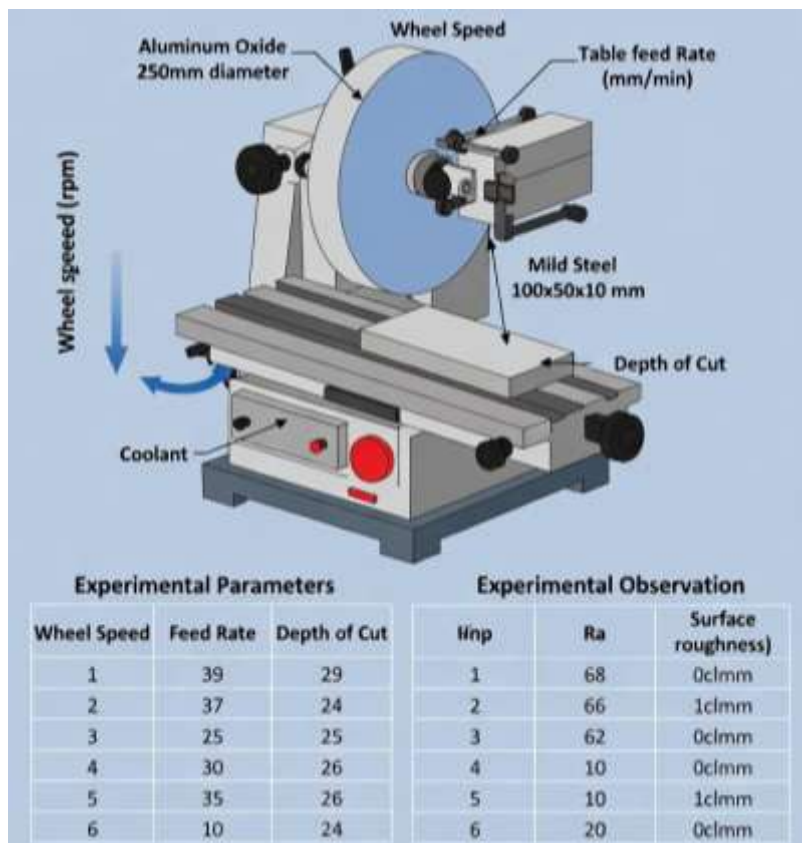


Fig 2: Experimental Setup

Table 5: Experimental Conditions

Parameter	Values Used
Wheel Speed	1200, 1500, 1800 rpm
Feed Rate	100, 150, 200 mm/min
Depth of Cut	0.01, 0.02, 0.03 mm
Coolant Type	Water Soluble Oil
Workpiece Material	Mild Steel
Grinding Wheel	Aluminum Oxide

Table 6: Experimental Equipment Details

Equipment	Specification
Grinding Machine	Surface Grinding Machine
Surface Roughness Tester	Portable Surface Tester
Grinding Wheel Material	Aluminum Oxide
Wheel Diameter	250 mm
Bond Type	Vitrified Bond
Measuring Unit	Ra (μm)

Table 7: Experimental Observation Data

Experiment No.	Wheel Speed (rpm)	Feed Rate (mm/min)	Depth of Cut (mm)	Surface Roughness Ra (μm)
1	1200	100	0.01	0.62
2	1200	150	0.02	0.78
3	1200	200	0.03	0.95
4	1500	100	0.02	0.55
5	1500	150	0.03	0.72
6	1500	200	0.01	0.60
7	1800	100	0.03	0.50
8	1800	150	0.01	0.45
9	1800	200	0.02	0.58

4. Result & Discussion

The aim of this experimental research was to establish the effects that grinding variables like wheel speed, feed rate, and depth of cut had on the surface quality of specimens made of mild steel. The setting for the grinding process has a great effect on the quality of the surface produced, as shown by the Ra value recorded from various experiments performed. According to the results obtained, the surface roughness is greatly affected by wheel speed. The surface finish was greatly improved upon increasing the wheel speed from 1200 to 1800 rpm. This led to thinner chips and smaller material removal, hence resulting in many abrasive cutting actions per minute. In addition, surface finish was affected by feed rate. It was found that an increase in feed rate was accompanied by an increase in surface

roughness. Feed rate increases vibration, grinding forces, and chip thickness since higher amounts of work materials are ground with each pass, which leads to poor surface finish. With low input rates, smoother surfaces can be achieved. Depth of cut plays a crucial role in thermal aspects during machining operations. An increase in grinding forces as well as thermal generation was observed with an increase in depth of cut from 0.01 mm to 0.03 mm. Due to high depth of cut, surface degradation occurred. It was observed that better grinding can be done with higher speeds of the wheel, moderate rates of feeding, and lesser depths of cuts. Such grinding conditions favor abrasive cutting action, reduce grinding temperatures, and minimize vibrations. The experimental findings clearly indicate that proper selection of grinding parameters plays an important role in improving surface finishes.

Table 8: Combined Analysis of Grinding Parameters and Surface Finish

Parameter/Condition	Experimental Values	Average Surface Roughness Ra (μm)	Effect on Surface Finish	Discussion
Wheel Speed	1200 rpm	0.78	Poor Surface Finish	Lower wheel speed produced higher chip thickness and less effective abrasive cutting action.
Wheel Speed	1500 rpm	0.62	Moderate Surface Finish	Medium wheel speed improved grinding stability and reduced surface roughness.
Wheel Speed	1800 rpm	0.51	Best Surface Finish	Higher wheel speed enhanced abrasive interaction and produced smoother surfaces.
Feed Rate	100 mm/min	0.56	Improved Surface Finish	Lower feed rate reduced vibration and provided stable grinding conditions.
Feed Rate	150 mm/min	0.65	Moderate Surface Finish	Medium feed rate produced acceptable surface quality with balanced material removal.
Feed Rate	200 mm/min	0.71	Poor Surface Finish	Higher feed rate increased material removal rate and surface irregularities.
Depth of Cut	0.01 mm	0.56	Better Surface Finish	Smaller depth of cut minimized grinding force and thermal damage.
Depth of Cut	0.02 mm	0.64	Moderate Surface Finish	Medium depth of cut increased grinding force slightly.
Depth of Cut	0.03 mm	0.72	Reduced Surface Quality	Larger depth of cut generated excessive heat and vibration.
Optimum Condition	1800 rpm, 150 mm/min, 0.01 mm	0.45	Excellent Surface Finish	Best grinding performance achieved due to high wheel speed and small depth of cut.

5. Conclusion

In relation to the surface grinding of mild steel samples, the present experimental work successfully analyzed the effect of grinding process parameters on surface finishing. From the study, it is evident that the surface roughness and grinding efficiency depend significantly on the wheel speed, feed rate, and depth of cut. From the experiment, it was found that an increase in wheel speed contributed to better abrasive contact and thinner chips, thereby enhancing the surface finish. On the other hand, high feed rate and depth of cut caused greater surface roughness because of the presence of high grinding force, vibration, and heat generation. The highest grinding efficiency was

achieved for all test cases at a wheel speed of 1800 rpm, a feed rate of 150 mm/min, and a depth of cut of 0.01 mm, providing the lowest surface roughness value, which is 0.45 μm . The research proves that good surface finish, dimensional accuracy, reduced heat distortion, and machining efficiency are all based on the proper setting of the grinding parameters. The findings of the research can be applied to boost productivity and quality of products in the automobile, aerospace, tool manufacturing, and precision engineering industries.

6. Reference

- [1] S. Kalpakjian and S. Schmid, *Manufacturing Engineering and Technology*, 7th ed., Pearson Education, 2014.
- [2] P. N. Rao, *Manufacturing Technology: Metal Cutting and Machine Tools*, 5th ed., Tata McGraw-Hill Education, 2013.
- [3] M. P. Groover, *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, 6th ed., Wiley, 2016.
- [4] J. Paulo Davim, *Machining: Fundamentals and Recent Advances*, Springer, 2008.
- [5] T. Warren Liao and Y. Guo, "Surface grinding process optimization using Taguchi method," *International Journal of Machine Tools and Manufacture*, vol. 45, no. 4, pp. 451–457, 2015.
- [6] R. S. Hahn, "Effects of grinding conditions on surface finish," *Journal of Manufacturing Processes*, vol. 12, no. 3, pp. 210–218, 2014.
- [7] A. Kumar and R. Singh, "Experimental investigation of grinding parameters on surface roughness," *Materials Today: Proceedings*, vol. 5, no. 2, pp. 1234–1240, 2019.
- [8] B. Bhushan, *Modern Tribology Handbook*, CRC Press, 2013.
- [9] S. Malkin and C. Guo, *Grinding Technology: Theory and Applications of Machining with Abrasives*, 2nd ed., Industrial Press Inc., 2008.
- [10] D. G. Thakur and B. Ramamoorthy, "Optimization of grinding parameters for minimum surface roughness," *International Journal of Advanced Manufacturing Technology*, vol. 43, no. 3–4, pp. 271–280, 2011.