# Effect of Process Parameters on Surface Roughness and Mrr in Cylindrical Grinding using Response Surface Method

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**Abstract - The main characteristics of grinding in comparison to other machining process are the relatively large contact area between the tool and work piece surface. The major limiting factor in grinding is thermal damage. The main purpose of grinding fluid can be categorized into lubrication, cooling, transportation of chips, cleaning of grinding wheel and minimizing corrosion.**

**In this paper, the effect of process parameters such as depth of cut, coolant flow rate and coolant nozzle angle are taken as variables. The present work aims at optimizing process parameters to achieve surface quality and high material removal rate in SAE 8620 steel material. Response surface method a powerful tool in design of experiments is used for optimization process.**

**Keywords: Cylindrical grinding, RSM, Coolant flow rate, Nozzle angle.**

## INTRODUCTION

Cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. As compared with other machining processes, Grindings costly operation that should be utilized under optimal conditions. Although widely used in industry, grinding remains perhaps the least understood of all machining processes. Cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. The major operating input parameters that influence the output responses, metal removal rate, surface roughness, surface damage, and tool wear, etc. are (i) wheel parameters: abrasives, grain size, grade, structure, binder, shape and dimension, etc. (ii) Work piece parameters: fracture mode, mechanical properties and chemical composition, etc. (iii) Process parameters: work speed, depth of cut, feed rate, dressing condition, etc. (IV) machine parameters: static and dynamic Characteristics, spindle system, and table system, etc. The present paper takes the following input processes parameters namely Work speed, feed rate and depth of cut. The main object tive of this paper is to show how our knowledge on grinding process can be utilized to predict the grinding behaviour 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. A software package has been developed which integrates these various models to simulate what happens during cylindrical grinding processes. Predictions from this simulation are further analyzed by calibration with actual data. It involves several variables such as depth of cut, work speed, feed rate, grit size, type of abrasive, chemical composition of wheel, etc.

The present work takes the following input parameters namely depth of cut, coolant flow rate and coolant nozzle angle by keeping other process parameters constant. The objective of this paper is to arrive at the optimum grinding condition that will minimize the surface roughness and maximize material removal rate when grinding SAE 8620 steel material.

The main objective in any machining process is to maximize the metal removal rate (MRR) and to minimize the surface roughness (Ra). In order to optimize these parameters response surface method is used.



## EXPERIMENTAL SET UP

*a) Design of experiments:* The input parameters which influence on surface quality and material removal rate (MRR) are taken as depth of cut, coolant flow rate and coolant nozzle angle. The Jones Shipman 1300 cylindrical grinding machine and grinding wheel of $Al_2O_3$ (A60 M6 VCNM) is used. The design of experiment was carried out by response surface methodology (RSM) using Minitab 14 software. This method is a collection of statistical and mathematical methods that are useful for the modeling and analyzing the engineering problems. In this technique the main objective is to optimize the response surface that is influenced by various process parameters. Response surface method also quantifies the relationship between the controllable input parameters and output responses.

*b) Controllable Variables:* The grinding parameters were coolant flow rate (Qc), depth of cut (Dc) and coolant nozzle angle (θc). Each factor has three levels (process ranges). The other factors such as grinding wheel speed, feed rate, work speed, abrasive and spark out were constant. The values of constant parameters are as follows; work speed 140 rpm, feed rate 540 mm/min and grinding wheel speed 2000 rpm.

*c) Response variables:* The surface quality in terms of surface roughness (Ra) in µm and material removal rate (MRR) in gms/sec are taken as output parameters for experimentation.

*d) Experimental set up:* A Series of experiment have been conducted to evaluate the influence of grinding process parameters on surface roughness and material removal rate in cylindrical grinding. The test was carried out on high precision cylindrical grinding machine with vitrified $Al_2O_3$ (A60 M6 VCNM) grinding wheel and water miscible coolant with 5 % concentration was supplied in all grinding experiments. The coolant supply is made through flexible segmented hose nozzle at different angles up to 20 tolerances and coolant is penetrated in the cutting zone. The flow rate of coolant is varied by the help of flow regulating valve. Dressing of grinding wheel is done by single point diamond dresser after every 10 experiments. SAE 8620 grade steel material used for experiments having 25 mm length and 80 mm diameter.

**e) Roughness measurement:** The surface roughness (Ra) is measured using Mitutoyo Surface Tester SJ 201 P for 0.8 mm of cut off length over a length of 4mm normal to the grinding surface at four different points on the work piece. The roughness value of each specimen in this research paper represents an average of five independent parameters.

**f) Weight measurement:** The weight of the samples taken before and after the experimentation as well. For weight measurement digital balance machine was used of Phoenix Gold 300 P having maximum capacity of 300 grams and minimum 0.2 grams having error value up to 0.01 grams. The material removal rate is calculated by taking weight difference and divided it by machining time.

EXPERIMENTAL PARAMETERS

The experiments were carried out on cylindrical grinding machine. There are three input controlling factors selected at three levels. Details of parameters and their levels are used shown in the table 1 below.

Table 1: Controlling factors and levels selected.

| Sr No | Factors | Notation | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| 1 | Coolant flow rate (lit/sec) | Qc | 0.008 | 0.037 | 0.066 |
| 2 | Depth of cut (µm) | Dc | 10 | 20 | 30 |
| 3 | Coolant nozzle angle (degrees) | θc | 0 | 45 | 90 |



The response surface study of central composite design (CCD) refers to evaluation of the anticipated model is obtained from Minitab14. The experimental design matrix is obtained by response surface methodology by using Minitab 14 software is shown in table 2 below.

Table 2: Experimental design matrix using RSM

| Standard Order | Flow rate (lit/sec) | Depth of cut (µm) | Nozzle angle (degree) | SAE 8620 | |
|---|---|---|---|---|---|
| | | | | Ra (µm) | MRR (gm/sec) |
| 1 | 0.008 | 10 | 0 | 0.61 | 0.184 |
| 2 | 0.066 | 10 | 0 | 0.63 | 0.185 |
| 3 | 0.008 | 30 | 0 | 0.8 | 0.221 |
| 4 | 0.066 | 30 | 0 | 0.75 | 0.222 |
| 5 | 0.008 | 10 | 90 | 0.62 | 0.183 |
| 6 | 0.066 | 10 | 90 | 0.64 | 0.184 |
| 7 | 0.008 | 30 | 90 | 0.8 | 0.22 |
| 8 | 0.066 | 30 | 90 | 0.76 | 0.221 |
| 9 | 0.037 | 20 | 45 | 0.65 | 0.214 |
| 10 | 0.037 | 20 | 45 | 0.65 | 0.214 |
| 11 | 0.037 | 20 | 45 | 0.64 | 0.214 |
| 12 | 0.037 | 20 | 45 | 0.65 | 0.214 |
| 13 | 0.008 | 20 | 45 | 0.64 | 0.212 |
| 14 | 0.066 | 20 | 45 | 0.64 | 0.213 |

| | | | | | |
|---|---|---|---|---|---|
| 15 | 0.037 | 10 | 45 | 0.6 | 0.185 |
| 16 | 0.037 | 30 | 45 | 0.78 | 0.224 |
| 17 | 0.037 | 20 | 0 | 0.66 | 0.213 |
| 18 | 0.037 | 20 | 90 | 0.67 | 0.212 |
| 19 | 0.037 | 20 | 45 | 0.65 | 0.214 |
| 20 | 0.037 | 20 | 45 | 0.65 | 0.214 |

## RESULTS AND DISCUSSION

It was observed the effects of depth of cut, coolant flow rate and coolant nozzle angle on surface roughness and material removal rate in cylindrical grinding. These results were shown in following mean effect plots.

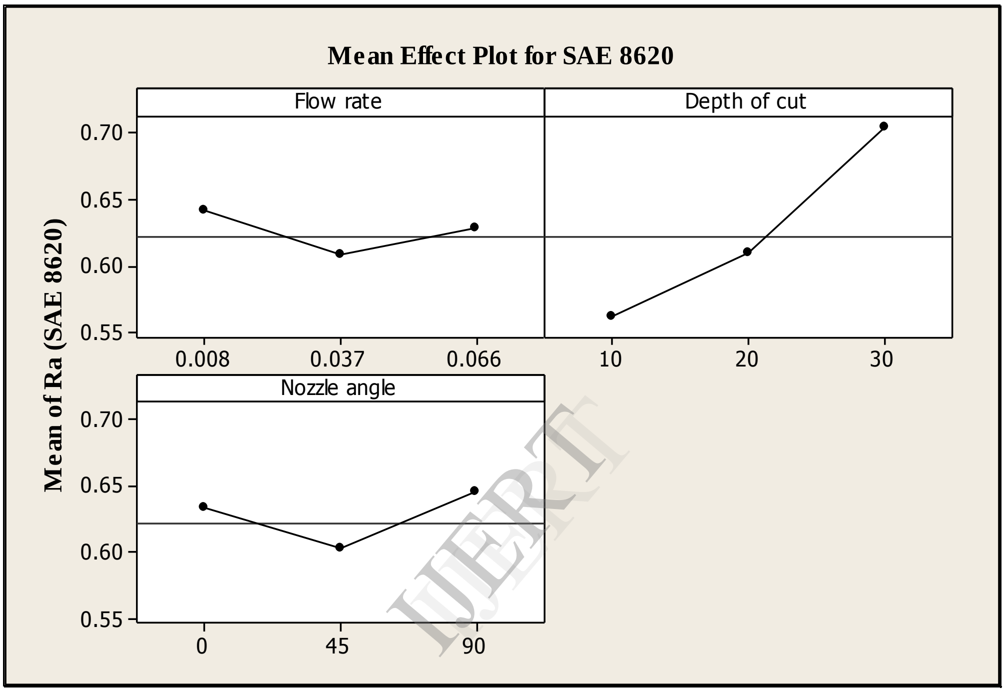


Fig.1 Mean Effect Plot of Ra for SAE 8620

The value of Ra decreases as flow rate increases from 0.008 lit/sec to 0.037 lit/sec. Further increase in flow rate results in increasing Ra value. The MRR also increases with increase in flow rate up to 0.037 lit/sec, after this value MRR is slightly lowers down. This shows that at intermediate values of flow rate Ra is minimum and MRR is maximum.

As the depth of cut increases, Ra value and MRR also increases linearly. For minimum Ra value depth of cut need to keep at lower side while for maximum MRR its value (depth of cut) at higher side. Depth of cut has maximum significant on Ra as well MRR. Ra value decreases with increase in nozzle angle up to $45^0$ and then again increases as the nozzle angle of coolant increases. At $45^0$ value of MRR is highest and its value minimum at $90^0$.

The value of Ra is max at min flow rate i.e. 0.008lit/sec and min at 0.037 lit/sec. It again increases with increase in flow rate. The MRR increases as flow rate increases

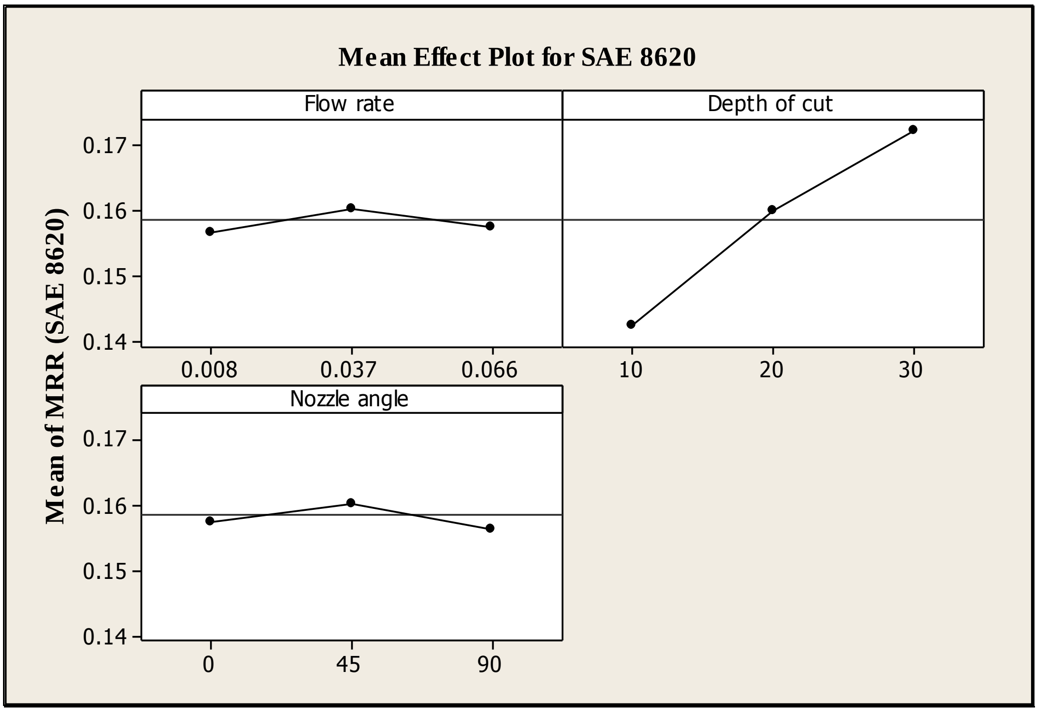


Fig.2 Mean Effect Plot of MRR for SAE 8620

up to 0.037 lit/sec, but again increase in flow rate results in decrease in MRR. Again MRR and Ra value increases with increase in depth of cut.

Depth of cut has direct and linear relation with MRR and Ra. Nozzle angle $45^0$ is found to most significant angle than $0^0$ and $90^0$. The response Ra and MRR for both materials is nearly same for three different controlling factors and their levels.



## CONCLUSIONS

This paper illustrates the importance of coolant flow rate and its angle of penetration in to grinding zone.

Coolant flow rate, depth of cut and nozzle angle can influence process productivity by improving surface quality and enhancing material removal rate. Optimization of coolant flow rate offers the chance to minimize the amount of coolant in circulation, thus reducing adverse environmental effects and costs. The present study shows the behavior of input grinding parameters on three different steel materials in terms of response Ra and MRR. The models develop by using Response Surface Method.

- For SAE 8620 grade steel, depth of cut followed by flow rate and nozzle angle was most influencing parameters on surface roughness and material removal also. The optimum set obtained for surface roughness (Ra), is $D_C$ = 10 µm, $Q_C$ = 0.037 lit/sec and θC = $45^0$.
- For MRR $D_C$ = 20 µm giving better output with medium flow rate and $45^0$ nozzle angle.
- From results it is suggested that for given type of steel material keeping coolant nozzle angle at $45^0$and medium flow rate of 0.037 lit/sec gives better cooling effect which lead to improve both productivity and surface quality
- Thus reducing the coolant supply and penetrating at $45^0$ nozzle angle will help to reduce coolant costs.

## REFERENCES

1. E. Brinksmeier ( I ) , C. Heinzel, M. Wittmann,"*Friction, Cooling and Lubrication in Grinding",* Key note papers, Bremen University, Division of Production Technology and IWT Bremen, Department of Manufacturing Technologies, Bremen, Germany
2. M. Kiyak, O. Cakir, E. Altan" *A Study on Surface Roughness in External Cylindrical Grinding"*,12th International Scientific Conference Achievements in Mechanical and Material Engineering
3. V.A. Baines-Jones, M.N. Morgan, D. R. Allanson, A.D.L Batako, *"Grinding Fluid Delivery System Design -Nozzle Optimisation",* AMTReL, GERI, Liverpool John Moores University
4. Leonardo Roberto da Silvaa, Eduardo Carlos Bianchib, Ronaldo Yoshinobu Fusseb, Rodrigo Eduardo Cataic, Thiago Valle Franc-ab, Paulo Roberto Aguiar, *"Analysis of surface integrity for minimum quantity lubricant—MQL in grinding",* International Journal of Machine Tools & Manufacture 47 (2007) 412–418

5. R. Alberdi, J.A.Sanchez, I.Pombo , N.Ortega , B.Izquierdo , S.Plaza , D.Barrenetxea, *"Strategies for optimal use of fluids in grinding",* International Journal of Machine Tools & Manufacture 51 (2011) 491–499
6. P Chockalingam, K Kok, R Vijayaram, "*Effect of Coolant on Cutting Forces and Surface Roughness in Grinding of CSM GFRP",* International Journal of Mechanical and Industrial Engineering 6 2012
7. T.Tawakoli, M.J.Hadad, M.H.Sadeghi, A.Daneshi, S.Stockert, A.Rasifard "*An experimental investigation of the effects of work piece and grinding parameters on minimum quantity lubrication—MQL grinding"* International Journal of Machine Tools & Manufacture 49 (2009) 924–932
8. M.Janardhan and Dr.A.Gopala Krishna," *Determination And Optimization Of Cylindrical Grinding Process Parameters Using Taguchi Method And Regression Analysis",* International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462, Vol. 3 No. 7 July 2011, page 5659-5665
9. Kirankumar R. Jagtap," *Optimization of Process Parameters in Cylindrical Grinding for AISI 5120 Steel using Taguchi method",* International Journal of Design and Manufacturing Technology (IJDMT), ISSN 0976-7002, Volume 2, Number 1, May-October 2011, page 47-56