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Research Paper

OPTIMIZATION OF CYLINDRICAL GRINDING PARAMETERS OF AUSTENITIC STAINLESS STEEL RODS (AISI 316) BY TAGUCHI METHOD

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Recently Austenitic stainless steel AISI-316 finding many applications like Automotive, Aerospace, Nuclear, Chemical and Cryogenics. The cylindrical grinding parameters on Austenitic stainless steel are conducted using Taguchi design of experiments of L9 orthogonal array was selected with 3 levels with 3 factors and output parameters of Metal removal rate are measured. After conducting experiment optimized by S/N ratio and analyzed by ANOVA and predict Cutting speed is a dominating parameter of cylindrical grinding.

Keywords: Austenitic stainless steel, Cylindrical grinding, Taguchi, S/N ratio ANOVA, Optimization

INTRODUCTION

The manufacturing process of centerless grinding has been established in the mass production of slim, rotationally symmetrical components. Due to the complex set-up, which results from the large sensitivity of this grinding process to a multiplicity of geometrical, kinematical and dynamical influence parameters, centerless grinding is rarely applied within limited-lot production. The substantial characteristics of this grinding process are the simultaneous guidance and machining of the workpiece on its periphery. 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. The major operating input parameters that influence the output responses, metal removal rate, surface

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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 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. 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 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 values taguchi method, ANOVA and regression analysis is used.

LITERATURE REVIEW

Janardhan and Gopala Krishna (2011), proposed that in cylindrical grinding metal removal rate and surface finish are the important responses. The Experiments were conducted 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. Cheol Lee (2009) proposes a control-oriented model for the cylindrical grinding process in the state-space format. A series of experiments were conducted to confirm the dynamic relationships and determine the model co efficients.It is found that multiple grinding cycles in batch production can be promptly predicted and analyzed using the proposed model. Alagumurthi *et al.* (2007) aims at optimizing the amount of heat generation and modeling the temperature rise between wheel and work contact zone in a cylindrical grinding process so as to achieve better surface integrity in AISI 3310, AISI 6150 and AISI 52100 steel materials of different carbon compositions using Al_2O_3 grinding wheel. Finally, it was concluded that plastic deformation is desirable and it dominates only when depth of cut is low; In case of rough grinding, i.e., with moderate depth of cut, the effect of plastic deformation and brittle fracture are medium; the temperature developed at the contact zone is the main cause for the phase transformation, i.e., austenite to marten site. Hassui and Diniz (2003) proposed that, the wear of a grinding wheel has a direct effect on the workpiece vibration and both have effect on the workpiece quality, the objective of the work was to study the relation between the process vibration signals and the workpiece quality (mean roughness, circularity and burning). In order to reach this goal, several experiments were carried out on a plunge cylindrical grinding operation on CNC cylindrical grinder of an AISI 52100 quenched and tempered steel (58 HRc). Deiva Nathan *et al.* (1999) proposed that, in the grinding process, a proper estimate of the life of the grinding wheel is very useful. When this life expires, redressing is necessary. Hardened C60 steel (Rc 40) specimens were ground with an A463-K5-V10 wheel in a cylindrical grinding machine. The results revealed that the surface quality and in-service behavior of a ground component is affected seriously by the occurrence of grinding burn. Hence, techniques for the prediction of the burn threshold are of great importance. Spark temperature can be considered to be a good representative of the grinding zone temperature. Stetiu and Lal (1974) studied that in grinding, wear is an integral part of the process and a wear rate that is too slow can easily be more undesirable in its consequences than a rapid one. The experiments were performed on an external cylindrical grinding machine. The cylindrical test work pieces were made from 0.5% carbon steel rod of hardness 52 HRc. Al_2O_3 vitrified bonded grinding wheels of three different hardness's (Grade J, K & M) were used having grain size 40 with a medium structure. It was concluded that the hardness of a grinding wheel is the most important property affecting the wear phenomena. Rodrigo *et al.* (2006) 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. Shih *et al.* (1998) proposed that, increasing the grinding wheel speed reduces the average chip thickness and increase the effective hardness of the wheel, resulting in more efficient workpiece material removal rates when the workpiece material is ceramic or steel. The grinding machine used in this study was Weldon AGN5 Cylindrical Grinding Machine. The grinding wheel used was vitreous bond CBN. He concluded that, during high speed grinding experiments of both zirconia and M2 steel, normal and tangential forces tend to lessen as the grinding wheel speed increases, but the surface finish is increases. Brinksmeier *et al.* (1999) explains that, in addition to coolant type, composition and filtration, coolant supply (nozzle position, nozzle geometry, and supplied flow rate and jet characteristics) can influence process productivity, workpiece quality and tool wear considerably. For this reason, the development of coolant system design should be a first priority. SAE 52100 steel with different hardness values with various types of coolant combinations, with various coolant supply strategies, and with various grades (Aluminum oxide and CBN) of grinding wheels have been used to optimize the cooling and lubrication process in grinding operation. It was concluded that coolant types, composition, nozzle design and flow rate can influence process productivity, workpiece quality and tool wear considerably. Kruszynski and Lajmert (2005) states that, the traverse grinding process is still considered to be an art and in most cases relies to a great extent on experience of machine tool operators who have been in the profession for years. Due to the decreasing number of such operators a strong need to support them by the application of supervision systems is observed that incorporate more intelligence with similar generalization adaptation abilities. For this reason, experimental investigations were carried out on a common cylindrical grinding machine. The material was 34CrA16C steel, hardened to 50 HRC. 38A80KVBE aluminum oxide grinding wheel of 495 mm diameter was used. He concludes that, there is a possibility of an effective application of artificial intelligence methods to supervise and control the cylindrical traverse grinding process. Also the metal removal rate can be maximized in very few grinding passes. Hon Zong Choi *et al.* (2002) states that, coolant promotes the effects of lubrication, cooling and penetration, but it contains chlorine, sulfur and phosphorus to improve the grinding efficiency. This is harmful to the workers and it also causes environmental pollution. A dry grinding method with compressed cold air and conventional wet grinding with coolant were compared (CNC Cylindrical Grinding). The experiments were performed with a White Alumina (WA) and a CBN wheel. The surface roughness and residual stress were measured to confirm the cooling effects of the compressed cold air. He concludes that, the surface roughness of the workpiece with compressed cold air is better than that with coolant and it becomes better as the air velocity increases. Rogelio Hecker and Steven Liang (2003) explains that, the quality of the surface generated by grinding determines many workpiece characteristics such as the minimum tolerances, the lubrication effectiveness and the component life, among others. A series of experiments were performed on cylindrical grinding.

PROBLEM IDENTIFICATION

The identification of machining and grinding problem for Austenitic stainless steel (AISI 316) which cannot be tackled using conventional technique because of following problems occurs in Grinding.

- Poor Chip Breaking.
- High Work hardened.
- Tendency to sticky.
- Transformation Induced plasticity.
- Affect the passive surface.
- Machining distortion

The above problems are to overcome during cylindrical grinding and achieve good surface finish and close dimensional accuracy.

EXPERIMENTAL SETUP

The goal of experimental work was to investigate the effect grinding parameters with the process parameters of cutting speed, feed rate and Depth of cut influencing the metal removal rate of AISI 316 Austenite stainless steel.The work material was AISI 316 Austenite stainless steel in the form of round rods with 50 mm diameters and length 70 mm (Figure 1). The work material was hardened and tempered to 55 HRC. The chemical composition of work material is shown Table 1.

Table 1: Chemical Composition of AISI316 Austenitic Stainless Steel

Cr	Ni	Mo	Mn	S	Si	C	P
18	14	3.0	2.0	0.03	0.75	0.08	0.045

TAGUCHI DESIGN OF EXPERIMENTS

Taguchi method is a powerful tool in quality Optimization makes use of a special design

Figure 1: AISI 316 Austenitic Stainless Steel Rods

of Orthogonal Array (OA) to examine. Number of experiments used to design the orthogonal array for 3 parameters and 3 levels of grinding parameters are shown in Table 2.

Table 2: Taguchi's Design of Experiments

Test No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

RESULTS AND DISCUSSION

Metal Removal Rate

After conducting the experiment on cylindrical grinding of austenitic stainless (AISI 316) 20 mm cylindrical rods of Metal removal rate are given below.

- Depth of cut is a dominating parameter of cylindrical grinding.
- The optimum parameter for Metal removal rate of cylindrical grinding of Austenitic stainless steel rods were 560 m/min of cutting speed, 0.130 mm of Feed and 0.05 mm of depth of cut are shown in Table 2.
- However Austenitic stainless steel (AISI 316) is good machinabilty characteristic and Produce excellent surface finish.
- Austenitic stainless steel produce good surface finish and get minimum crack tendency.

Table 3: Cylindrical Parameters of Metal Removal Rate

Test No.	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	MRR (mm^3/min)
1	560	0.073	0.003	10.32
2	560	0.093	0.004	17.53
3	560	0.130	0.005	30.63
4	780	0.073	0.040	14.67
5	780	0.093	0.005	23.37
6	780	0.130	0.003	19.60
7	1000	0.073	0.004	15.59
8	1000	0.093	0.005	24.83
9	1000	0.130	0.003	20.82

Figure 2: Maineffect Plot for Metal Removal Rate

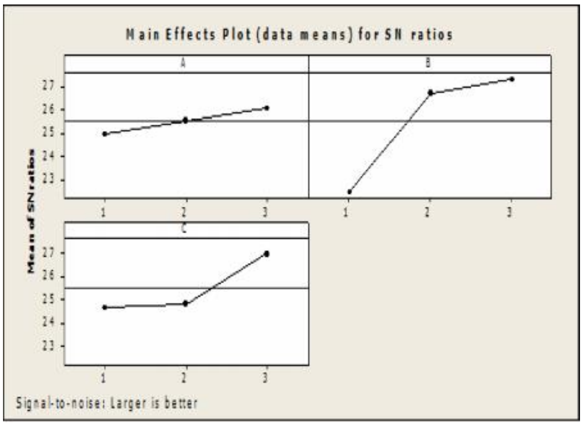


Table 4: ANOVA for Metal Removal Rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	2	2.36	2.36	1.18	0.04	0.963
B	2	176.58	176.58	88.29	2.89	0.257
C	2	55.31	55.31	27.65	0.90	0.525
Error	2	61.14	61.14	30.57		
Total	**8**	**259.40**				

Figure 3: Contour Plot for Metal Removal Rate

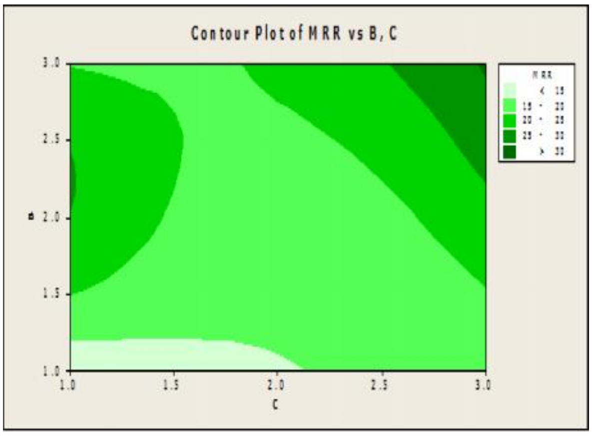
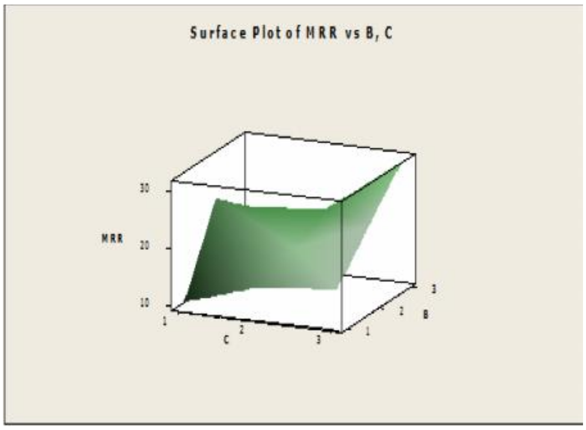


Figure 4: Surface Plot for Metal Removal Rate



The Figures 3 and 4 denotes the graphical analysis of optimum parameters of metal rate during grinding performed in cylindrical grinding process of Austenitic stainless steel rods (AISI 316). It is mentioned metal removal rate is increased by Depth of cut in level 3 in surface plot diagram and contour plot denotes depth of cut is increased in level 3. This may optimum parameter of cylindrical grinding process of Austenitic stainless steel (AISI 316) rods.

CONCLUSION

After conducting experiments on cylindrical grinding, I conclude the following:

- Austenitic stainless steel produces good surface finish during cylindrical grinding process in optimum grinding parameters.
- Close tolerance can be achieved during cylindrical grinding.
- Depth of cut play an important role in cylindrical grinding and produce maximum metal removal rate in AISI 316 austenitic stainless steel were 560 m/min of cutting speed 0.130 mm and 0.005 mm of depth of cut.
- Austenitic stainless (AISI 316) Provide good machinability property.
- The influence parameter of surface roughness is cutting speed and metal removal rate is influenced by Depth of cut.
- The optimum parameters of cylindrical grinding overcome problem of poor chip breaking and machining distortion.

REFERENCES

1. Alagumurthi N, Palaniradja K and Soundararajan V (2007), "Heat Generation and Heat Transfer in Cylindrical Grinding Process—A Numerical Study", *International Journal of*

Advance Manufacturing Technology, Vol. 34, pp. 474-482.

2. Brinksmeier E, Heinzel C and Wittmann M (1999), "Friction, Cooling and Lubrication in Grinding", *Annals of the CIRP*, Vol. 48, No. 2.
3. Cheol W Lee (2009), "A Control-Oriented Model for the Cylindrical Grinding Process", *International Journal of Advance Manufacturing Technology*, Vol. 44, pp. 657-666.
4. Comley P, Walton I, Jin T and Stephenson D J (2006), "A High Material Removal Rate Grinding Process for the Production of Automotive Crankshafts", *Annals of the CIRP*, Vol. 55, No. 1, p. 9.
5. Deiva Nathan R, Vijayaraghavan L and Krishnamurthy R (1999), "In-Process Monitoring of Grinding Burn in the Cylindrical Grinding of Steel", *Journal of Materials Processing Technology*, Vol. 91, pp. 37-42.
6. Dhavlikar M N, Kulkarni M S and Mariappan V (2008), "Combined Taguchi and Dual Response Method for Optimization of a Centerless Grinding Operation", *Journal of Materials Processing Technology*, Vol. 132, Nos. 1-3, pp. 90-94.
7. Hassui A and Diniz A E (2003), "Correlating Surface Roughness and Vibration on Plunge Cylindrical Grinding of Steel", *International Journal of Machine Tools & Manufacture*, Vol. 43, pp. 855-862.
8. Hon Zong Choi, Suk Woo Lee and Hae Do Jeong (2002), "The Cooling Effects of Compressed Cold Air in Cylindrical Grinding with Alumina and CBN Wheels", *Journal of Materials Processing Technology*, Vol. 127, pp. 155-158.
9. Janardhan M and Gopala Krishna A (2011), "Determination and Optimization of Cylindrical Grinding Process Parameters Using Taguchi Method and Regression Analysis", Vol. 3, pp. 5659-5665, *International Journal of Engineering Science and Technology*.
10. Kruszynski B W and Lajmert P (2005), "An Intelligent Supervision System for Cylindrical Traverse Grinding", Institute of Machine Tools and Production Engineering, Poland.
11. "Optimization of Grinding Parameters for Minimum Surface Roughness by Taguchi Parametric Optimization Technique", *International Journal of Mechanical and Industrial Engineering (IJMIE)*, pp. 60-66.
12. Resit Unal and Edwin B Dean (1997), "Taguchi Approach to Design Optimization for Quality and Cost", Annual Conference of the International Society of Parametric Analysts, pp. 1-10.
13. Rodrigo Daun Monicia, Eduardo Carlos Bianchia, Rodrigo Eduardo Cataib and Paulo Roberto de Aguiar (2006), "Analysis of the Different Forms of Application and Types of Cutting Fluid Used in Plunge Cylindrical Grinding Using Conventional and Superabrasive CBN Grinding Wheels", *International Journal of Machine Tools & Manufacture*, Vol. 46, pp. 122-131.

14. Rogelio L Hecker and Steven Y Liang (2003), "Predictive Modeling of Surface Roughness in Grinding", *International Journal of Machine Tools & Manufacture*, Vol. 43, pp. 755-761.

15. Shaji S and Radhakrishnan V (2003), "Analysis of Process Parameters in Surface Grinding with Graphite as Lubricant Based on the Taguchi Method", *Journal of Materials Processing Technology*, Vol. 141, No. 1, pp. 51-59.

16. Shih A J, Grant M B, Yunushonis T M, Morris T O and McSpadden S B (1998), "Vitreous Bond CBN Wheel for High Speed Grinding of Zirconia and M2 Tool Steel", *Transactions of NAMRI/SME*, Vol. 26.

17. Stetiu G and Lal G K (1974), "Wear of Grinding Wheels", *Wear*, Vol. 30, pp. 229-236.

18. Venkatesh P K, Bobji M S and Biswas S K (1999), "Power Spectra of Roughness Caused by Grinding of Metals", *Journals of Material Research*, Vol. 14, pp. 319-322.

19. Yang W H and Tarang Y S (1998), "Design Optimization of Cutting Parameters for Grinding Operations Based on Taguchi Method", *Journal of Material Processing Technology*, Vol. 84, pp. 122-129.