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Optimization of Metal Removal Rateon Cylindrical Grinding For Is 319 Brass Using Taguchi Method

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ABSTRACT
Cylindrical grinding is one of the most important metal cutting processes used extensively in the Metal finishing operations. Metal removal rate and surface finish are the important output responses in the production with respect to quantity and quality respectively. The objective of this paper is to arrive at the optimal grinding conditions that will maximize metal removal rate when grinding IS 319 brass. Empirical models were developed using design of experiments by Taguchi L9 Orthogonal Array and the adequacy of the developed model is tested with ANOVA.
Keywords-Cylindrical Grinding, IS 319 Brass, Metal Removal Rate, Taguchi Analysis, ANOVA, S/N Ratio.

I. INTRODUCTION

Cylindrical grinding is a metal cutting operation performed by means of abrasive particle rigidly mounted on rotating wheel. Each of the abrasive particle act as single point cutting tool and grinding wheel acts as a multipoint cutting tool.

The grinding process is frequently considered as one of the most complex and difficult-to-control manufacturing processes due to its complex, nonlinear, and stochastic nature. Therefore, controlling the grinding process for the improvement of its yield and productivity would often require a highly sophisticated control framework **[1]**. The main input parameters that influence the output responses, metal removal rate, surface roughness, and temperature etc. are (i) Process Parameters: work speed, depth of cut, feed rate, dressing condition, etc. (ii) Machine Parameters: static and dynamic characteristics, spindle system and table system etc. (iii) Wheel Parameters: abrasives, grain size, grade, Structure, binder, shape and dimension, etc. (iv) Work piece Parameters: fracture mode, mechanical properties and chemical composition, etc**[2]**.

II. LITERATURE REVIEW

Choi et al. [1] established the generalized model for power, surface roughness, grinding ratio and surface burning for various steel alloys and alumina grinding wheels. It was shown that these models can predict process conditions over a wide range of grinding conditions.

KirankumarRamakantraoJagtap et al.[2] investigated the effect of cutting parameters (depth of cut (Dc), Work Speed (N_w), Number of Passes (N_p) and Grinding Wheel Speed (Ns)) and the responses considered are surface roughness (Ra) and material removal rate (MRR) in cylindrical grinding using orthogonal array and Taguchi method. In this study, an optimized set of three input parameter is estimated for max MRR & min R_a.

Janardhan et al. [3] 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.

Jae-SeobKwak, et al. [4] analyzed the surface roughness of the product and grinding power spent during the process in the external cylindrical grinding of hardened SCM440 steel using RSM. It was found that the depth cut is more influential factor than the traverse speed for the grinding power and an increase in infeed changes the maximum height of the surface roughness more than the center line average height.

Kruszynski et al [5] 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 and 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.

Shaji and Radhakrishnan[6] presented a study on Taguchi method to evaluate the process parameters in surface grinding with graphite as lubricant. The effect of process parameters such as speed, feed, infeed and modes of dressing are analyzed.

Stetiu et al [7] 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. Al2O3 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.

Monici et al [8] 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.

Saglam et al. [9] investigated the effect of cutting parameters (grinding force, infeed, work speed and feed rate) on roundness error and surface roughness in cylindrical grinding using orthogonal array and Taguchi method. In this study, it is reported that the roundness is mostly influenced by the cutting speed, grinding force and depth of cut, whereas surface roughness is related to feed rate and work speed.

Shih et al [10] proposed that, increasing the grinding wheel speed reduces the average chip thickness and increase the effective hardness of the wheel, resulting in more efficient work piece material removal rates when the work piece 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[11] 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, work piece 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 (Aluminium 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, work piece quality and tool wear considerably.

Nathan et al [12] 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.

Comley et al [13] explains that, high efficiency deep grinding (HEDG) with its high material removal rate helps to improve cycle times while maintaining surface integrity, form and finish requirements. Thermal modeling is used to optimize the grinding cycle for an automotive steel and cast iron. He finally demonstrated that the concept of HEDG was valid for cylindrical plunge grinding using the selected steel and cast iron materials, and there was no abrasive grit or wheel failure as a result of the higher loads associated with the HEDG system at MRR up to 2000mm3/mm/s.

Hecker et al [14] explains that, the quality of the surface generated by grinding determines many work piece characteristics such as the minimum tolerances, the lubrication effectiveness and the component life, among others. A series of experiments were performed on cylindrical grinding. The material used was hardened steel 52100 (62 HRc) with an aluminum oxide grinding wheel. He found that, the predicted surface roughness shows a good agreement with experimental data obtained from different kinematic conditions in cylindrical grinding.

Table 1: Chemical Composition of IS 319 Brass

IS 319 Designation	Cu	Pb	Fe	Zn
IS 319 Brass	58.37	2.85	0.36	38.42

III. EXPERIMENTAL SET-UP AND DESIGN OF EXPERIMENT

For present work, IS 319 Brass has been selected as work material. The chemical composition of IS 319 brass is shown in Table 1.The diameter and length of these 09 workpieces were 35mm and 75mm respectively. The tests were carried out on High Precision Cylindrical Grinding Machine with vitrified Al_2O_3 grinding wheel (300mm X 127mm X 40mm). Water miscible coolant with 5% concentration was supplied in all grinding experiments. The input parameters are depth of cut (Dc), Work Speed (Nw), and Grinding Wheel Speed (Ns), and the response considered was metal removal rate (MRR).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.Process variables and their levels have been shown in Table 2, whereas the design of experiment based on Taguchi's L9 Orthogonal Array method is shown in Table 3. The obtained values of responses are then compared with predicted values of regression equations. Minitab 17 version statistical software is used to generate regression equations and for analysis of obtained data Taguchi Method is used.

Table 2: Process variables and their levels for cylindrical grinding process using IS 319 Brass

Level	**Depth of cut (Dc)µm**	**Work speed (Nw)rpm**	**Grinding wheel speed (Ns)rpm**	**Remark**
1	200	40	11000	Low
2	400	60	17600	Medium
3	600	80	2500	High

Table 3: Design of Experiment for Grinding of IS 319 Brass

Run	Dc (µm)	Nw (rpm)	Ns (rpm)	MRR(gm/s)
01	200	40	11000	0.260
02	200	60	17600	0.202
03	200	80	25600	0.196
04	400	40	17600	0.303
05	400	60	25600	0.275
06	400	80	11000	0.311
07	600	40	25600	0.325
08	600	60	11000	0.323
09	600	80	17600	0.314

Table 4: Estimated Model Coefficients for S/N ratios (Metal Removal Rate)

Term	Coef	SE Coef	T	P
Constant	-11.235	0.132	-84.83	0.000
Dc 200µm	-2.014	0.187	-10.75	0.009
Dc 400µm	0.659	0.187	3.52	0.072
Nw 40rpm	0.624	0.187	3.33	0.080
Nw 60rpm	-0.405	0.187	-2.16	0.163
Ns 11000rpm	0.682	0.187	3.64	0.068
Ns 17600rpm	-0.207	0.187	-1.10	0.385

IV. RESULTS AND DISCUSSIONS

Table 6 and Figure 1 depict the factor effect on metal removal rate. The higher the signal to noise ratio, the more favorable is the effect of the input variable on the output. The graph shows that, the optimum value levels for best metal removal rate (maximum) are at a depth of cut 200 µm, work speed 40 rpm, and grinding wheel speed of 11000 rpm.

It can be seen that the most influencing parameter to metal removal rate for IS 319 Brass is depth of cut (Dc) in µm,followed by Grinding wheel speed and work speed.

S = 0.397337 R-Sq = 98.64% R-Sq (adj) = 94.58%

Table 5: Analysis of Variance for S/N ratios (Metal Removal Rate)

Source	DF	Adj SS	Adj MS	F Value	P Value
Dc	2	18.984	9.492	60.12	0.016
Nw	2	1.804	0.902	5.71	0.149
Ns	2	2.198	1.099	6.96	0.126
Error	2	.315	0.157		
Total	8	23.302			

Table 6: Response Table for Signal to Noise Ratios – Larger is better (Metal Removal Rate)

Level	Depth of Cut(μm)	Work Speed(rpm)	Grinding Wheel Speed (rpm)
1	-13.249	**-10.611****	**-10.554****
2	-10.576	-11.641	-11.442
3	**-9.880****	-11.454	-11.710
Delta	3.370	1.029	1.156
Rank	1	3	2

****indicates higher S/N Ratio**

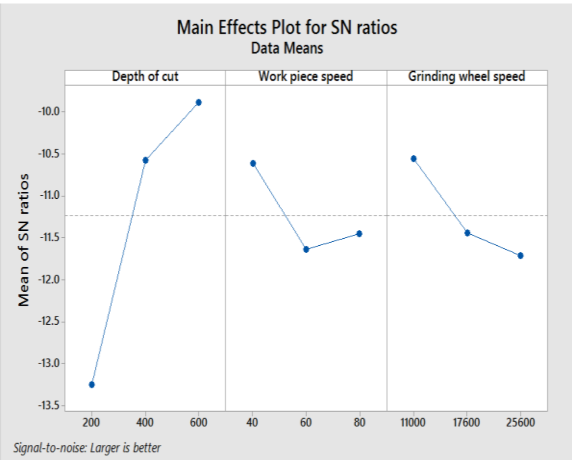

Fig 1: Main Effect Plot of S/N ratios for Metal Removal Rate

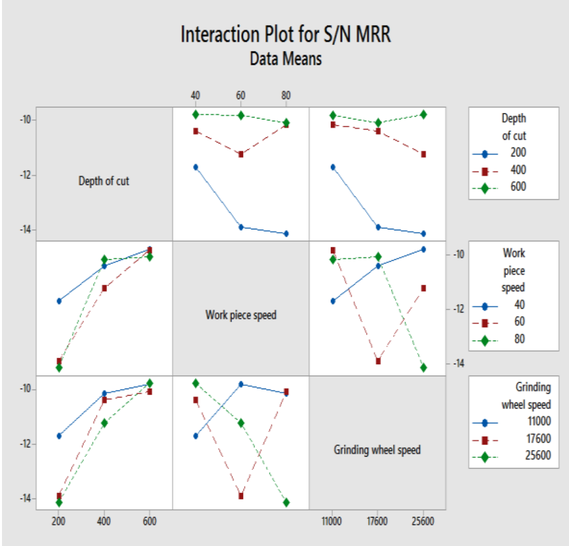

Fig 2: Interaction Plot for S/N Ratios of Metal Removal Rate

For validation, the predicted values obtained by regression equation for Metal Removal Rate are compared with the experimental values.

Also, the optimum set of parameters obtained from analysis is shown in Table 7.

Regression Equation for Metal Removal Rate for grinding of IS 319 Brass

MRR=0.27878-0.05944Dc200+0.01756Dc400+0.04189Dc600+0.01722Nw40-0.01211Nw60-0.00511Nw80+0.01922Ns11000-0.00578Ns17600-0.01344Ns25600

Table 7: Optimum Set of Parameters

Optimal Set For	Controlled Factors	Optimum Set
Metal Removal Rate (MRR in gm/s)	Dc (μm)	200
	Nw (rpm)	40
	Ns (rpm)	11000

V. CONCLUSIONS

For Metal Remove (MRR), the depth of cut (μm) was the most influencing factor for IS 319 Brass work material followed by grinding wheel speed and work speed.

So, to achieve the maximum metal removal rateof IS 319 Brass, employ depth of cut of 200μm, work speed of 40 rpm and grinding wheel speed of 11000 rpm.

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