Optimize Grinding Process Parameter to Achieve Minimum Roughness Using Taguchi Parameter Optimization Technique

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ABSTRACT

Cylindrical grinding is one of the important metal cutting processes used extensively in the finishing operations. Surface finish is the important output responses in the production with respect to quantity and quality respectively. The Experiments are conducted on universal tool and cutter grinding machine with L9 Orthogonal array with input machining variables as work speed, grinding wheel grades and hardness of material. The developed model can be used by the different manufacturing firms to select right combination of machining parameters to achieve an optimal surface roughness (Ra).The results reveals surface roughness (Ra).The predicted optimal values for Ra for Cylindrical grinding process is 1.07 Ra respectively. The results are further confirmed by conducting confirmation experiments.

Key worlds - Grinding, Taguchi, hardness Roughness, S/N ratio, Regression

1. 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.

The present paper takes the following input processes parameters namely material hardness, work piece speed and grinding wheel grain's. 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. The main objective in any machining process is to minimize the surface roughness (Ra).In order to optimize these values taguchi method, is used.

2. Taguchi Method

Taguchi method is the process of engineering optimization in a three step approach namely system design, parameter design and tolerance design. In the system design, a basic functional prototype design will be produced by applying scientific and engineering knowledge. In parameter design, independent process parameter values will be optimized and where as in tolerance design, tolerances will be determined and analysed for optimal values set by parameter design. Taguchi method is a powerful design of experiments (DOE) tool for optimization of engineering processes.

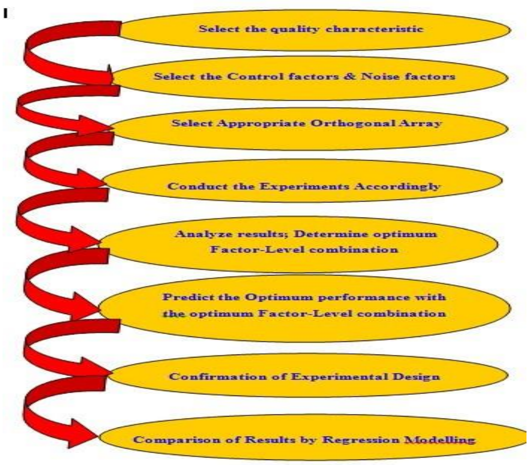

Figure 1 Steps of taguchi method

3. Experimental Setup and Cutting Conditions

3.1 Work piece material

The work piece material selected for investigation is EN 24, EN31 and Die steel. This steel can be hardened and tempered to provide a greater strength

and wear resistance in comparison of low carbon steels. The work piece used for experiment is round bar with 30 mm diameter and 75 mm length.

3.2 Machining Process

The cutting tests were performed on universal tool and cutter grinding machine and Aluminum oxide white grinding wheel. The experiments were conducted as per the orthogonal array and roughness for various combinations of parameters was measured using Deviate DH 5 tester.

3.3 Plan of Experiment

The experiment was planned using Taguchi's orthogonal array in the design of experiments, which help in reducing the number of experiments. The L_9 orthogonal array.

Table3.1 parameters and their levels for experiment

Level	Material hardness (HRC) H	Workpiece speed (r.p.m) W	Grinding wheel (grains) G
1	50	100	G46
2	55	160	G60
3	60	200	G80

Table 3.2 L9 orthogonal array

Experiment	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	3
5	2	2	1
6	2	3	2
7	3	1	2
8	3	2	3
9	3	3	1

3.4 Experimental Details

A set of experiments were conducted on tool and cutter grinding machine on different alloy steel of different hardness material to determine effect of parameters namely),Work speed (rpm),material hardness and grinding wheel on surface roughness Ra(μm). Three levels and three factors L9 Orthogonal array used to design the orthogonal array by using design of experiments (DOE) .Grinding wheel used for the present work is the aluminum oxide abrasive with verified bond with constant speed of 2850 RPM. The jobs have undergone turning and hardening processes before grinding. Hardening is done for better output response and the HRC is maintained.

Table3.3 consolidated design of experiment table

Experiment	**Combination of input factors**	**Output Response (Roughness)**
1	$H_1W_1G_1$	2.20
2	$H_1W_2G_2$	1.65
3	$H_1W_3G_3$	1.10
4	$H_2W_1G_3$	1.59
5	$H_2W_2G_1$	1.90
6	$H_2W_3G_2$	1.07
7	$H_3W_1G_2$	1.31
8	$H_3W_2G_3$	1.46
9	$H_3W_3G_1$	2.11

Lower is better S/N =-10 log [1/n (Σyi2)] “Eq. (1)”

Table 3.4 S/N ratio summary sheet

Experiment No.	S/N ratio
1	-6.85
2	-4.35
3	-0.83
4	-4.03
5	-5.58
6	-0.59
7	-2.35
8	-3.29
9	-6.49

Average of S/N Ratio = -3.82 dB

Average S/N ratio for each parameter at three level

Table 3.5 S/N ratio table for surface roughness

		Low	Medium	High
H	Material Hardness (sH)	-4.01	**-3.4**	-4.04
W	Workpiece speed (sW)	-4.41	-4.41	**-2.64**
G	Grinding wheel (sG)	-6.31	**-2.43**	-2.72

Average Roughness for each parameter at three levels
Tabl 3.6 mean response table for surface roughness

S. No	Parameter	Surface roughness		
		Low	Medium	High
H	Material Hardness (HRC)	1.65	**1.52**	1.63

W	Wokpiece speed (RPM)	1.70	1.67	**1.43**
G	Grinding wheel (G)	2.07	**1.34**	1.38

The optimum level for a factor is the level that gives the highest value of parameter in each level in the experimental region denoted by bold letter. The estimated main effects can be used for this purpose.

4. Main Effects

Main effects plots for the experiments have been given below.

4.1 Response Graphs for Means

1. Level II for Hardness, H2 = 1.52 Ra indicated as the optimum situation in terms of Surface Roughness values.

2. Level III for Cutting Speed, W3 = 1.43Ra indicated as the optimum situation in terms of Surface Roughness values.

3. Level II for Grain's, G2 = 1.34Ra indicated as the optimum situation in terms of Surface Roughness values

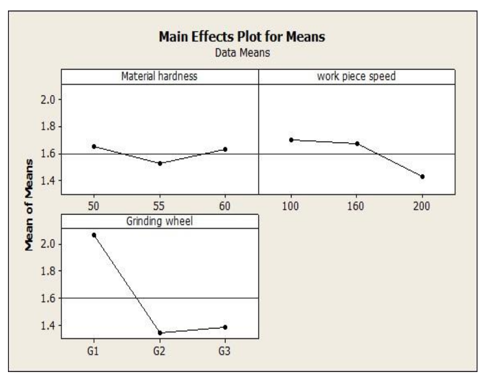

Fig 4.1. Effect of process parameter on Roughness

4.2 Response Graphs for S/N values for Surface Roughness

(a) Level II for Hardness, sH2 = -3.4 dB indicated as the optimum situation in terms of S/N values.

(b) Level III for work piece speed, sW3 = -2.64 dB indicated as the optimum situation in terms of S/N values.

(c) Level II for Grain's, sC2 = -2.43 dB indicated as the optimum situation in terms of S/N values.

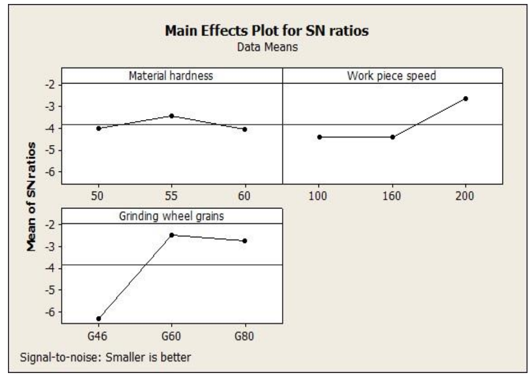

Fig4.2 Main effect for S/N ratio .

5.1 Results

From main effects plotted, it is observed that there is decreases surface roughness as material hardness increased. The roughness decreases when speed is changed from 100 to 160 rpm and again decreases when speed changed to 200 rpm, similarly when grinding wheel grain's change from G46 to G60 surface roughness decreases, but as again change to G80 roughness increase considerably.

5.2 Conformation of Experiment

To validate the optimum grinding conditions (H2, W3, G2) the combination of Medium Hardness (H2), Larger Wokpiece speed (W3) and Medium Grain's (G2) , then the Surface Roughness is minimum obtained

Table 5.1 conformation of experiment

Surface Roughness (Ra)	S/N ratio (dB)
1.07	-0.59

5.3 Mathematical regression Modelling

For the combination of parameters, roughness value is tabulated. Empirical formula has fined out by using regression modeling.

Modelling of parameters

To generalize the results, the Modeling of input parameters (Hardness, work piece speed, grain's) and output parameter (Roughness) is done using REGRESSION MODELLING and MATLAB Software R2011b.

$$\mathbf{Ra = 105.90\ (Hardness)^{0.0078} * (Work\ piece\ Speed)^{-0.2492} * (Grinding\ wheel)^{-0.7340}}$$

5.4 Comparison of Result

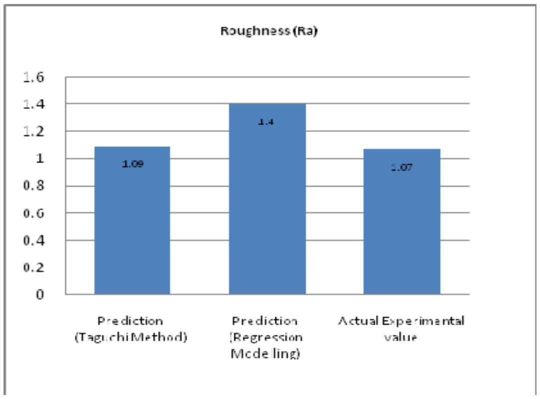

Fig 5.1 comparison of results

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