Study on Surface Roughness and its Prediction in Cylindrical Grinding Process based on Taguchi method of optimization

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Abstract- This seminar presents the experimental work/project done on studying the working of cylindrical grinding machine and effect of its process parameters at Govt. Engineering College, Thrissur. 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 MILANO RICEN RUM 1 Cylindrical Grinding Machine with L9 Orthogonal array with input machining variables as work speed, depth of cut and hardness of material. Surface roughness is measured using MITUTOYO Surf test SJ-400 surface roughness tester. 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). It also formulates an empirical relationship between the surface roughness values and the input parameters. Taguchi parametric optimization is used for the optimization process. The results are further confirmed by conducting confirmation experiments

Index Terms- Cylindrical grinding machine, Taguchi, surface roughness, S/N ratio, depth of cut, design of experiments, analysis of variance

I. INTRODUCTION

Cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. The various process parameters of a cylindrical grinding machine include depth of cut, material hardness, work piece speed, grinding wheel grain size, and grinding wheel speed.

The present paper takes the following input processes parameters namely material hardness, work piece speed and depth of cut. The main objective is to predict the grinding behaviour in terms of surface roughness and achieve optimal operating processes parameters. For optimization process Taguchi optimization technique is used. [1]

II. OBJECTIVES

To understand the cutting mechanisms involved in cylindrical grinding. To study the effect of cutting speed, material hardness & depth of cut on surface roughness with other parameters set constant. To create an empirical relationship between the surface roughness value obtained and the process parameters. To test the equations found out using experimental and analytical techniques.

III. EXPERIMENTAL PROCEDURE

A. *Experiment*

Study the effect of depth of cut, material hardness and work piece speed on surface roughness with other parameters set constant.

B. *Procurement of material*

Alloy steels of various compositions are brought from EMVEE Agencies, Coimbatore. EN 24, EN31 and EN 353 are the grades of alloy steels used. Alloy steels rods are of 32mm diameter and 300mm in length. Work pieces are centre drilled and turned in a universal lathe machine.

C. *Grinding of work pieces*

After turning, work pieces are grinded in cylindrical grinding machine. (MILANO RICEN RUM 1 MACHINE) Carborundum grinding wheel- AA46K5V40 is used as grinding wheel. Soluble oil used as cutting fluid. The various process parameters of a cylindrical grinding machine include depth of cut, material hardness, work piece speed, grinding wheel grain size, and grinding wheel speed. The present paper takes the following input processes parameters namely material hardness, work piece speed and depth of cut. The other parameters such as abrasive type and feed rate are kept constant. The number of experiments to be conducted can be reduced by using orthogonal array method of Taguchi optimization technique.

LEVEL	1(low)	2(medium)	3(high)
Depth of Cut	10	15	20
Speed	60	75	120
Hardness	50	60	64

Fig 1 Selected process parameters

Design of Experiments – L9 orthogonal array

Experiment No:	Hardness	speed	Depth of cut
1	50	60	15
2	50	120	20
3	50	75	10
4	60	60	10
5	60	120	15
6	60	75	20
7	64	60	10
8	64	120	20
9	64	75	15

Fig 2 L9 orthogonal array

D. *Surface roughness measurements*

Surface roughness values are obtained from MITUTOYO Surftest SJ-400 Surface roughness tester for each experiment. The obtained values used for the Taguchi optimization process.

Experiment No:	Hardness	speed	Depth of cut	Surface Roughness
1	50	60	15	0.76
2	50	120	20	0.56
3	50	75	10	0.79
4	60	60	10	0.72
5	60	120	15	0.61
6	60	75	20	0.57
7	64	60	10	0.69
8	64	120	20	0.47
9	64	75	15	0.59

Fig 3 Figure showing surface roughness value obtained

Signal to Noise ratio is found out in each case using the criteria ‘ lower is better’ as surface roughness is the factor of consideration.

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

Experiment No	SNRA1
1	2.383
2	5.036
3	2.047
4	2.853
5	4.293
6	4.882
7	3.223
8	6.558
9	4.582

Fig 4 Signal to noise ratio for various experiments

Average S/N ratio for each parameter at each level is found out. Similarly the average surface roughness values for each parameter at each level are also found out.

Level	Hardness	Speed	Depth of cut
1- Low	3.156	2.820	2.708
2- Medium	4.010	3.838	3.753
3- High	4.788	5.296	5.492
Delta	1.632	2.476	2.784
Rank	3	2	1

Fig 5 Average S/N ratios in each level

Signal to noise ratio is high when hardness value is in level three, speed is in level three and depth of cut is in third level. The difference between the largest and minimum signal to ratio is calculated and the factors effect are ranked based on it.

Level	Hardness	Speed	Depth of cut
1- Low	0.703	0.723	0.733
2- Medium	0.633	0.650	0.653
3- High	0.583	0.546	0.533
Delta	0.120	0.177	0.200
Rank	3	2	1

Fig 6 Average surface roughness values in each level

Surface Roughness (Ra value) is low when hardness value is in level three, speed is in level three and depth of cut is in third level. The difference between the largest and minimum surface roughness value is calculated and the factors effect are ranked based on it.

E. *Main effects plots*

Main effects plots for the experiments have been given below.

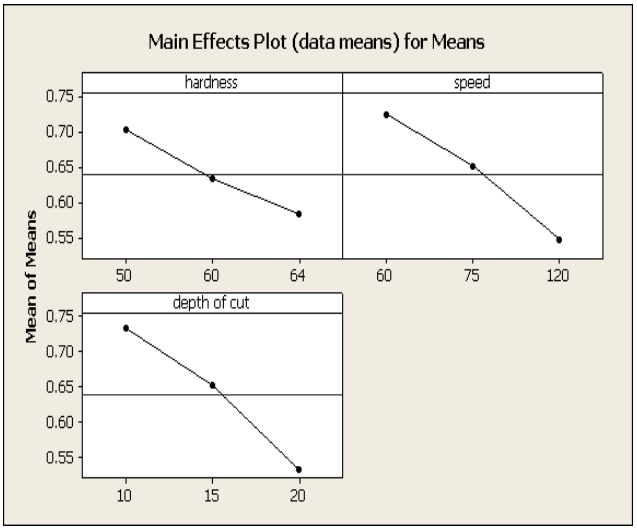

Fig 7 Response Graphs for Mean surface roughness

1. Level III for Hardness, H3 = 0.583 Ra indicated as the optimum situation in terms of Surface Roughness values.
2. Level III for Cutting Speed, W3 =0.546 Ra indicated as the optimum situation in terms of Surface Roughness values.
3. Level III for depth of cut, D3 = 0.533Ra indicated as the optimum situation in terms of Surface Roughness values

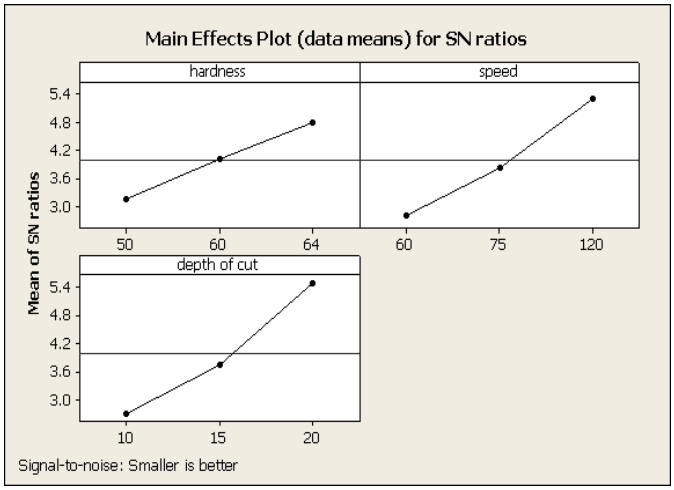

Fig 8 Response Graphs for S/N values for Surface Roughness

1. Level III for Hardness, S/N H3 = 4.788dB indicated as the optimum situation in terms of S/N values.
2. Level III for Cutting Speed, S/N W3 = 5.296dB indicated as the optimum situation in terms of S/N values.
3. Level III for depth of cut, D3 = 5.492 dB indicated as the optimum situation in terms of S/N values.

IV. MODELLING OF RESULTS

F. *Annova test*

One way Annova test is carried out and the result obtained is found to be significant from the F value obtained.

Analysis of Variance

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.086819	0.028940	56.07	0.000
Residual Error	5	0.002581	0.000516		
Total	8	0.089400			

G. *Mathematical regression Modelling*

The obtained surface roughness values for each experiment are tabulated and empirical formula is formulated using mathematical regression modelling.

Regression equation obtained is
The regression equation is
C5 = 1.45 - 0.00827 A - 0.00126 B- 0.0150 C, where
C5 – Surface Roughness, A – Hardness, B – Speed , C – Depth of Cut

H. *Taguchi optimization result*

From main effects plotted, it is observed that there is decrease in surface roughness as material hardness increased. The surface roughness decreases when speed increases from 60 to 120 rpm, similarly when depth of cut increases from 10 to 20 surface roughness decreases.

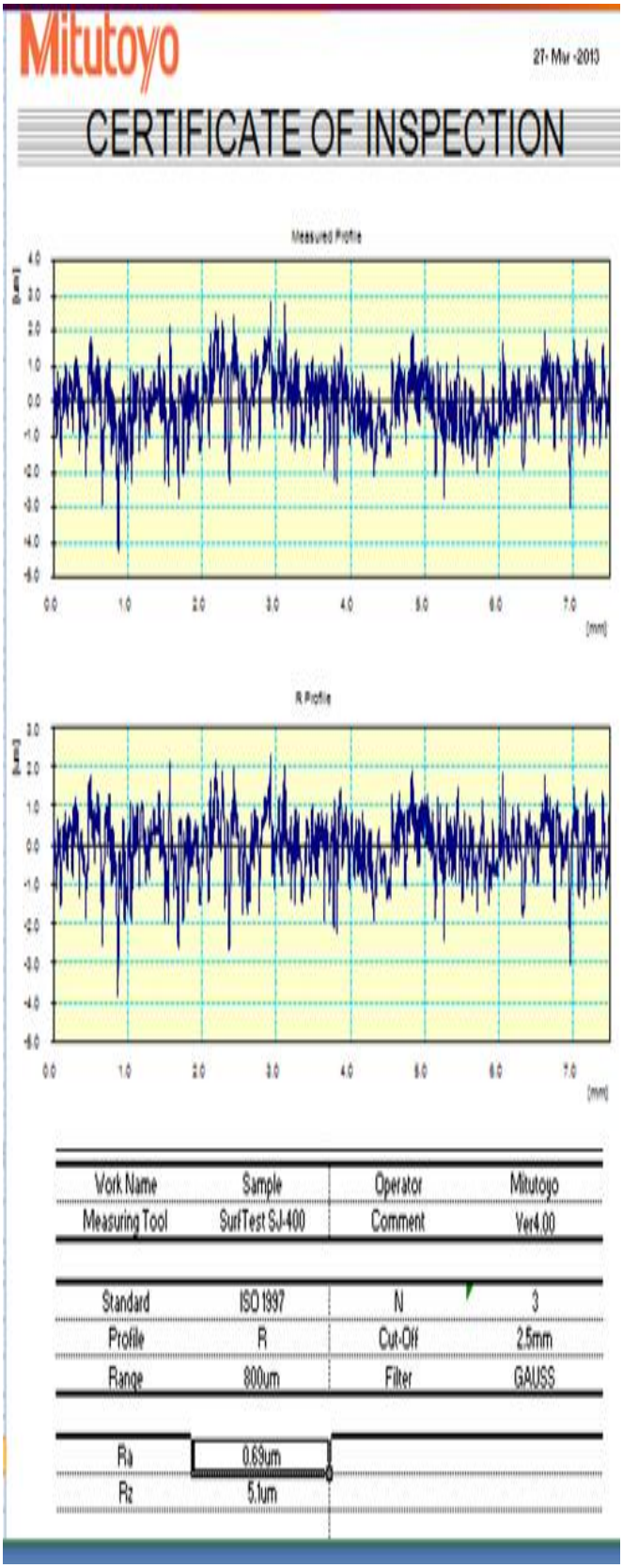

Fig 9 Reading obtained from MITUTYO Surftest surface roughness tester for Experiment No:5.

I. *Conformation of Experiment*

To validate the optimum grinding conditions (H3, W3, D2) the combination of High Hardness (level – 3) (H3), High Wok piece speed (level – 3) (W3) and High depth of cut (level – 3) (D3), then the Surface Roughness is minimum obtained

Table 1: Conformation of experiment

Surface roughness	S/N ratio found out
0.47	6.558

Comparison of results

Optimum surface roughness value obtained using Taguchi parametric optimization is 0.47 Ra. Confirmation experiments yields the result surface roughness equal to 0.47Ra. Surface roughness obtained using regression modelling equation is 0.469Ra.

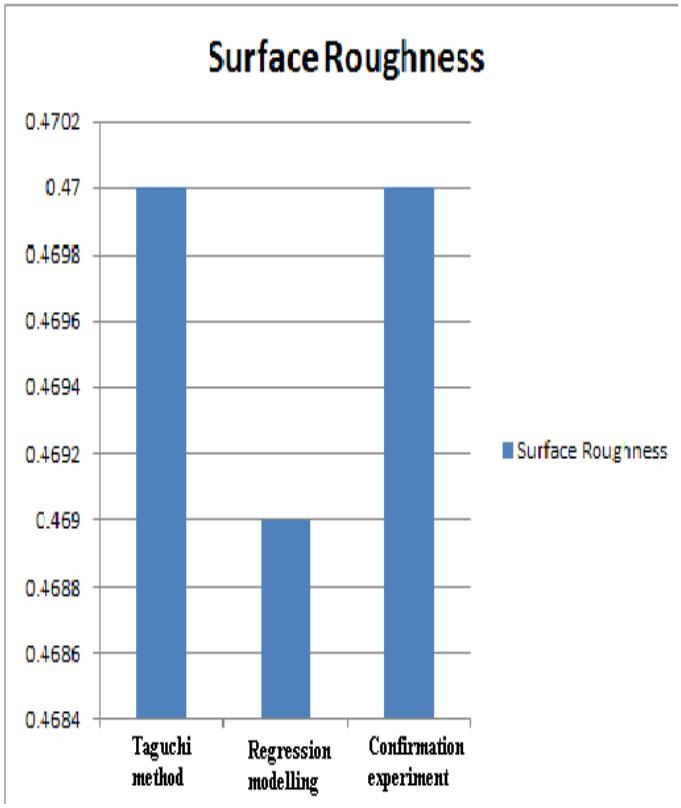

Fig 11 Comparison of results

V. CONCLUSIONS

This paper attempts to develop an analytical model for surface roughness in MILANO RICEN RUM 1 Cylindrical Grinding Machine . Based on the analytical and experimental results obtained in this study following conclusions can be drawn.

1. Grinding process and various parameters affecting surface roughness are studied and analyzed.
2. Surface roughness value measurement using MITUTYO surftest surface roughness tester is studied.
3. Emperical equation relating various process parameters is formulated. Regression equation is formulated.
4. Optimum values of depth of cut, hardness, and speed which gives minimum surface roughness are found out using taghuchi optimization technique.

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