QUALITY IMPROVEMENT THROUGH OPTIMIZATION OF PARAMETERS OF HONING PROCESS

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Abstract: *The surface quality of any cylinder bores with improved sliding properties is often produced by the honing process. This multi-stage process is performed using abrasive tools fed against the bore with simultaneous rotary and oscillatory motion. To have process robustness with acceptable dimensional accuracy and surface quality, the various process parameters have to be studied deeply. This paper aims to improve the quality of honing process by optimizing and analyzing the cylinder liner surface roughness which is influenced by various process parameters during honing. Conducting the experimental runs according to the design of experiment and analyzing the results which are finally validated through confirmation experimentation.*

Keywords: *Honing, Design of Experiment, Analysis of Variance (ANOVA), S/N Ratio, Response Surface Method*

1. INTRODUCTION

Honing is a fine finishing abrasive machining process with a multi-edge cutting tool of bonded grains under constant surface contact between tool and pre-machined components, which offers good geometrical tolerances. It is a controlled, low speed sizing and surface finishing process in which stock is removed by the shearing and plugging action. The present study aimed to optimization of the cylinder liner surface roughness influence process parameters during honing. Many more honing processes and its influence parameters were frequently used by industries to perform honing of cylinder liner of four stroke petrol engine, but improvement further desire for more customer satisfaction. Selection of honing stone and grit size depends mainly on the desired rate of metal removal and the required surface finish. Honing provides a cost effective alternative to other finishing processes like grinding, lapping and super finishing. To reach higher production accuracy and better process stability in shorter cycle times, new approaches for the regulation of an automated honing process have to be developed. Due to the great demands regarding the surface roughness which has a great influence on the service life and reliability of parts and the researches of the technical and economical performances of finishing processes were made to optimize the process parameters and constructive parameters of the abrasive tools

2. PREVIOUS WORK

2.1. Literature Review

A literature review of the recently published research work on the honing process is carried out to understand the research issues involved and is presented here.

Misra et al.(2011) This paper reports on high-precision finishing of gears by Electrochemical Honing (ECH) process. It is one of the most potential micro-finishing process in which material is removed by anodic dissolution combined with mechanical abrasion of bonded abrasive grains. The precision finishing of gears by ECH is a productive, high accuracy, long tool life gear finishing process. The present study contains a detailed description of the process principle, influencing parameters, process capabilities, equipment details, applications, effects of input parameters, developed regression models, surface integrity aspects of machined surface and comprehensive literature review of past research work on the ECH of gears along with some guidelines for further research with an objective to revive the interest of the global research community to mature this process further.

Damir S. Vracet al.(2012) Purpose – The purpose of this paper is to explore the influence of tool kinematics parameters on surface roughness, productivity and cutting angle for grey cast iron cylinder liners machined by normal honing. For experimental investigation, a long stroke honing system was used. Diamond and SiC tools were used, for preand finishing, respectively. The values of cutting parameters were varied within the following limits: cutting speed vs ¼ 0.931-1.11 m/s; specific pressure of pre-honing process pd ¼ 1.0-1.4 N/mm2 and specific pressure of finishing honing process pz ¼ 0.2-0.5 N/mm2. The analysis of dispersion was conducted for determining the mathematical model for cutting parameter influence on surface roughness and productivity. Dispersion analysis proved that the most influential parameters on maximum roughness depth are cutting speed for D181 tool and specific pressure of finishing honing for D151 tool. The most influential parameter on productivity in the honing process with D181 and D151 tool is cutting speed. Originality/value – The paper gives new information related to the normal honing optimization process. Normal honing offers the highest surface quality which is achieved by a low speed machining. However, that means also a relatively low productivity, demanding a thorough process optimization. Furthermore, normal honing is usually done by ECH pre-honing and mechanical finishing honing, but in this paper, all-mechanical honing was used for the same result, at a lower lost.

B. Goeldel et al.(2013) this paper is thus to develop a macroscopic simulation environment which will help end-users during this setting-up stage. The development of this virtual tool is based on a space-time discretization and a macroscopic cutting model taking into account local contacts between the workpiece and the abrasive stones. The space-time discretization allows representing the machine environment including the tool, the work piece and the machine kinematics. The cutting model allows converting kinematics and abrasive contacts in dynamic data and material removal rate by calculation. The cutting model is initially adjusted based on simple experiments. The stock removal equation is then extrapolated to the whole range of stone cutting conditions. This approximation allows simulating the real process and a whole honing cycle. Results are validated by comparison with industrial context experiments. The simulation of the whole honing cycle allows predicting the form quality, one of the roughness criteria and the surface appearance. Moreover, simulation results are represented by means of maps that allow looking at quality criteria for each point of the surface.

Damir Vrac et al.(2014) In this paper, an attempt was made to study the dependencies between average and maximum roughness in relation to material removal rate and specific volume material removal rate of long-stroke honing in relation to different abrasive grain size tools and honing speeds. Long-stroke honing was performed on grey cast iron cylinder liners. It was found that by using a finer grain tool, lower roughness and similar material removal rate is obtained. Inconsistent relation between average and maximum roughness in relation to material removal rate and specific volume material removal rate were described by abrasive grain stress in honing tools. Abrasive grain stress influences the fall-out of abrasive grains from the tool surface and their uncontrolled movement over the sample – tool system. This results in a stochastic workpiece material removal, which is more severe if the abrasive grains are larger in the corresponding tool.

H. Singh et al.(2015) The effects of processing time, electrolyte composition and electrolyte concentration on the electrochemical honing (ECH) performance under direct current and pulse current condition were studied. ECH is a hybrid machining processes used for finishing internal cylinders, gun barrels and gears, based on the combination of electrochemical machining (ECM) process having high material removal capability and controlled functional surface generating capability of conventional honing process in a single operation. It is reported that the material removal rate of ECH is two to eight times higher than the conventional gear finishing processes and can provide better surface finish value to Ra 0.05 µm and hence its benefits can be widely used for aerospace, automobile, gear manufacturing, nuclear reactor applications etc. Moreover, the pulse assistance in ordinary ECH provides the relaxation period to the ECM zone of the system during pulse-off time to discharge the dregs out of the inter electrode gap and thus improves the process capability for maximizing the service life and overall performance of gears. Based on the experimental findings at the optimum setting of input process parameters, pulse current shows an improvement of 22.73 percent in average surface roughness and 13.48 percent in maximum surface roughness value of EN8 spur gear as compared to direct current. SEM images have revealed that finished surface having uniform structure and free of scratches and micro-cracks.

Aniket Kishor Deshpande et al.(2015) In this paper, an attempt was made to study the dependencies between average and maximum roughness in relation to long-stroke honing to different abrasive grain size tools and honing speeds using old and new plateau honing concept. A study to investigate the effect of cylinder liner honing angle on hydrodynamic lubrication between piston ring and cylinder liner. Honing angles between 25-75° were investigated to find the effect of honing angle on film thickness. The plateau-honing is an ultra-finishing process as a result of two machining processes: rough honing with big size abrasive grains and finish honing with very small size abrasive grains to eliminate peaks on the surface of the piece. It is a very complex process depending on many parameters.

Pimpalgaonkar M.H et al.(2013) The MRR and surface roughness play an important role in productivity improvement. Surface finish increases as well as MRR increases. Gray cast iron (BHN 150) as selected a work piece material. In this paper input parameter are selected like feed pressure and spindle speed and output parameters are MRR and surface roughness respectively. Also three factors and their levels are selected. In this paper Taguchi orthogonal Lg array is selected. In this method silicon carbide material is used for honing stick. This paper is related with the optimization process parameters which are carried out on hydraulic vertical honing machine. The speed selection depends upon hardness of crank case material as well as diameter of the bore to be finished. The spindle speed range between 150rpm - 700rpm. The coolant is used as servo park-2 or honing oil is used. In this method regression analysis and Anova technique is implementation. S/N ratio larger is better for MRR and S/N ratio smaller is better for surface roughness. The results revealed that using MRR gets as stroke pressure increases. From response table and graph has the rank indicates stroke pressure has greatest effect on MRR and the rank indicates the feed pressure has a greatest effect on surface roughness. The objectives of research summarized that feed pressure increases as its surface roughness decreases.

2.1.1 Literature Review Outcomes & Research Issues

Following research issues are identified from literature review and are summarized as below,

1. Different coolant supply methods are not included in the research and their effect on the quality is not reported.
2. It is observed that, few studies have been conducted in the literature to study combined effect of process parameter on the response parameter.
3. Little work reported for analysis of tool using different grades of tool coatings.
4. Relatively less work is reported for analysis of tool wear.
5. Very few researchers worked on taper and roundness.

2.2 Research Statement

The quality of honing operation is influenced by the various process parameters. The relationship between and influence of different process parameters need to be identified and be analyzed with the purpose of establishing control over the process and optimizing the process.

3. DESIGN OF EXPERIMENT

In order to identify which process parameters influence the surface as well as in what way they do, experiments were performed. At the first stage of study, the honing parameters directly affected on surface quality in honing process were determined. For this purpose, Speed, Feed, Tool grit, Nozzle diameter were chosen with three different levels depending on recommendation of honing tools manufacturer that is Sunnen.

For design of experiment following factors and levels are consider.

Table 3.1: Level of Process Parameters

Sr. No.	Factors	Level	Level Values
1	Speed (rpm)	3	700, 800, 900
2	Feed(mm/min)	3	500, 600, 650
3	Tool Grit	2	60/80, 80/100
4	Nozzle Diameter (mm)	2	5, 8

3.2 Experimentation

The effect of honing parameters (Speed, Feed, Tool grit, Nozzle diameter) on surface roughness is presented in honing of an automotive component name as engine rocker arm. By considering factors and their combined levels, L36 orthogonal array is selected. The total of 36 experiments were conducted according to Taguchi orthogonal array with respect to parameters controlled in machining processes. The honing parameters were evaluated as independent variables while average surface roughness (Ra) were evaluated as dependent variable in this study.

4. MEASUREMENT OF RESPONSE PARAMETER (S/F ROUGHNESS)

4.1 Surface Roughness Measurement

"Surface roughness is a component of surface texture . It is quantified by the deviations in the direction of normal vector of a real surface from its ideal form". Surface roughness nomenclature is as shown in Figure (4.1.1).

In this work, Surface roughness will be measured with help of Mitutoyo surface roughness tester on internal wall of the hole on specimen. It is measured in µm. This is a small, lightweight, and extremely easy to use as surface roughness measurement instrument that lets you view surface roughness value on the screen.

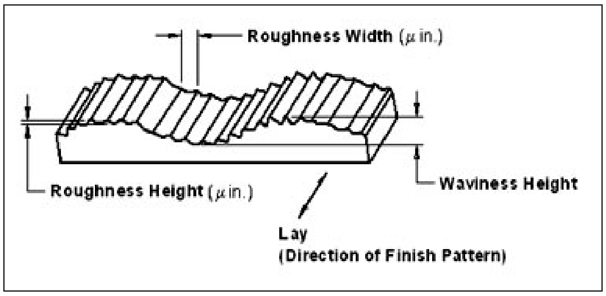

Fig 4.1.1. Surface Roughness Nomenclature

Fig 4.1.2. Surface Roughness Tester

4.2 Experimental Results

The assessment of experimental results was done via graphs and statistical analyses with obtained data. The surface roughness values from rough honing experiments and S/N ratios calculated by "the smaller the better" method is given in Table 4.2.1

5. DATA ANALYSIS

The final phase of the design of experiment is to analyze and interpret the experimental results to improve the performance characteristics of the product or process relative to customer needs and expectations. After all tests are conducted, decisions must be made concerning which parameters affect the performance of a product or process. For this the ANOVA is an extremely useful technique which is used when multiple sample cases are involved. The basic principle of ANOVA is to test the means of the population by examining the amount of variation within each of this sample relative to the amount of relation between the samples. In terms of variation within the given population, The first step in data analysis is to summarize the data for each experiment. For each experiment appropriate S/N ratio for response outputs are calculated. (Ross P.J., 1996)

5.1 Response Surface Method

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. The objective is to optimize a response (output variable) which is influenced by several independent variables (input variables).

If all the independent variable are measurable, continuous and controllable by experiments with negligible errors, the response surface can be expressed by,

$Y = f(x1 + x2 + x3 + \ldots\ldots + xk)$

where, y is the response of the system, f is the true response function whose form is unknown and perhaps very complicated, xi is the variable of action called factor, and k is the number of independent variables. In order to optimize the response "y", it is, therefore essential to find a

Table 4.2.1: Experimental Results for Surface Roughness

Exp. Run	Speed (S)	Feed (F)	Tool grit size(TS)	Nozzle dia.(D) (mm)	Trial 1	Trial 2	Average
					S/F Roughness (Ra)		Ra
1	700	500	60/80	5	0.76	0.7	0.73
2	800	500	60/80	5	0.57	0.56	0.565
3	900	500	60/80	5	0.69	0.65	0.67
4	700	500	60/80	8	0.66	0.62	0.64
5	800	500	60/80	8	0.8	0.72	0.76
6	900	500	60/80	8	0.61	0.75	0.68
7	700	500	80/100	5	0.33	0.39	0.36
8	800	500	80/100	5	0.44	0.38	0.41
9	900	500	80/100	5	0.31	0.33	0.32
10	700	500	80/100	8	0.37	0.34	0.355
11	800	500	80/100	8	0.4	0.3	0.35
12	900	500	80/100	8	0.33	0.34	0.335
13	700	600	60/80	5	0.68	0.65	0.665
14	800	600	60/80	5	0.65	0.58	0.615
15	900	600	60/80	5	0.67	0.67	0.67
16	700	600	60/80	8	0.69	0.72	0.705
17	800	600	60/80	8	0.67	0.7	0.685
18	900	600	60/80	8	0.68	0.58	0.63
19	700	600	80/100	5	0.38	0.3	0.34
20	800	600	80/100	5	0.37	0.32	0.345
21	900	600	80/100	5	0.37	0.39	0.38
22	700	600	80/100	8	0.39	0.4	0.395
23	800	600	80/100	8	0.38	0.36	0.37
24	900	600	80/100	8	0.37	0.31	0.34
25	700	650	60/80	5	0.7	0.7	0.7
26	800	650	60/80	5	0.6	0.67	0.635
27	900	650	60/80	5	0.82	0.81	0.815
28	700	650	60/80	8	0.8	0.76	0.78
29	800	650	60/80	8	0.5	0.64	0.57
30	900	650	60/80	8	0.69	0.73	0.71
31	700	650	80/100	5	0.35	0.42	0.385
32	800	650	80/100	5	0.36	0.33	0.345
33	900	650	80/100	5	0.38	0.39	0.385
34	700	650	80/100	8	0.35	0.36	0.355
35	800	650	80/100	8	0.42	0.36	0.39
36	900	650	80/100	8	0.41	0.37	0.39

suitable approximation for the true functional relationship between the independent variables and the response surface. The postulated mathematical model used with response surface designs is typically a second degree model with second-order interactions as given below,

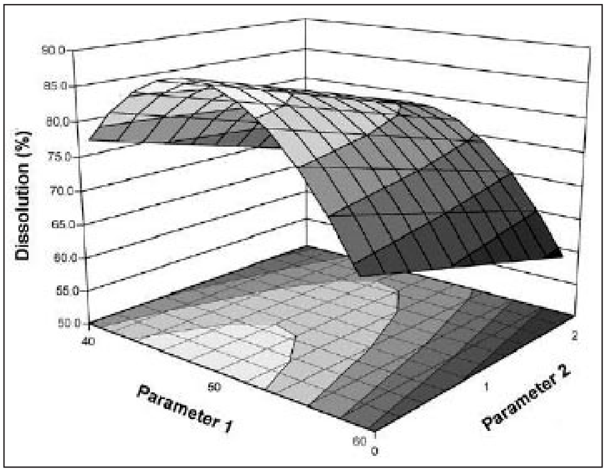

Fig 5.1.1. Response Surface

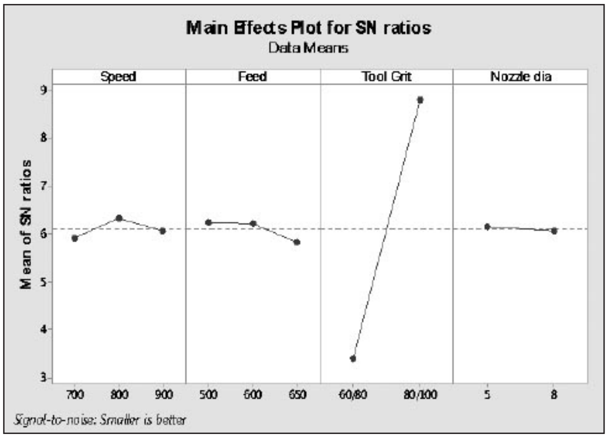

Fig 6.1.1. Main Effect Plot of S/N Ratio for Surface Roughness

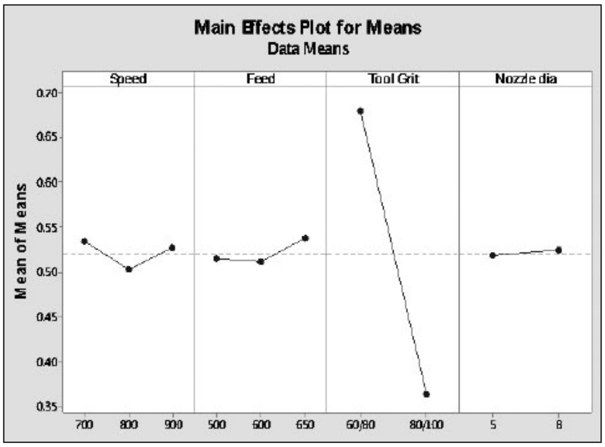

Fig 6.1.2. Main Effect Plot for Means

$Y = \beta0 + \beta1x1 + \beta2x2 + \beta3x3 + \beta11x12 + \beta22x22 + \beta33x32+\beta11x1x2 + \beta12x1x3 + \beta13x2x3$

Where, β0, β1…… β13 are called regression coefficient and x1, x2, x3are the controllable factors.

Generally, the response surface represent graphically as shown in figure 5.1.1 to help visualize response surface.

In counter plot, lines of constant response are drawn in the x, y planes. Each counter corresponds to particular height of the response surface. In most RSM problem, the form of relationship between the response and independent variable is unknown. Thus the first step in RSM is to find suitable approximation for the true functional relationship between response and independent variable.

6. RESULTS

6.1 Determination of Significant Process Parameters for Surface Roughness by ANOVA Method

In main effect plot of S/N ratio for surface roughness, X-Axis indicates different levels of process parameters and Y-Axis shows average of S/N ratio. It can be observed from Figure 6.1.1 that, surface roughness decreases up to the speed of 800 rpm, as speed increases beyond 800rpm surface roughness start increasing. with increase in feed initially surface roughness decreases and later on it start increasing. Surface roughness is minimum for tool grit 80/100. Nozzle diameter has no significant effect on surface roughness.

As seen from Table 6.1.2, tool grit is the most influence parameter for surface roughness followed by speed, feed and nozzle diameter.

6.2 Predicted Result by Taguchi Method

When the optimal level of process parameters is determined then next step is to predict and validate the improvement of the performance measures with help of optimal level. The optimal level for different performance parameters are given below.

a) For surface roughness : -S2-F2-T2-N1

By using confirmation experiment, we can verify the conclusion that obtained from analysis.

Table 6.1.1 : Analysis of Variance for Surface Roughness

Source	DF	Adj.SS	Adj.MS	F value	P value	% contribution
Speed	2	0.006260	0.003130	1.23	0.308	0.3438
Feed	2	0.005135	0.002567	1.00	0.378	0.2836
Tool Grit	1	0.894601	0.894601	350.16	0.000	99.33
Nozzle diameter	1	0.000306	0.000306	0.12	0.732	0.03
Error	29	0.074090	0.002555			
Total	35	0.980391				

Table 6.1.2 : Response Table for S/N Ratios for Ra value, Smaller is Better

Level	Speed	Feed	Tool Grit	Nozzle diameter
1	0.5342	0.5146	0.6792	0.5186
2	0.5033	0.5117	0.3639	0.5244
3	0.5271	0.5383		
Delta	0.0308	0.0267	0.3153	0.0058
Rank	2	3	1	4

Table 6.3.1 : Coefficient of Factor for Surface Roughness

Term	Coefficient
Constant	0.303
S	-0.000035
F	0.000132
Tool grit	-0.3153
Nozzle diameter	0.00194

Table 7.1 : Confirmation of Experiments for Surface Roughness

	Prediction	Experiment
Level	S2-F2-T2-N1	
surface roughness (µm)	0.3639	0.34

6.3 Prediction of Optimal Value of Surface Roughness by using following Regression Equation

Once the optimal level of the geometry parameters is identified, the final step is to predict and validate the improvement of the performance measures using the optimal level, i.e. for surface roughness S2-F2-T2-N1. The purpose of the confirmation experiment is to verify the conclusions drawn during the analysis phase.

The response was correlated with the factors using the first order polynomial. The relationship between surface roughness and process parameters as shown in table 6.3.1

Regression Equation

Ra value =

1. Tool Grit 60/80 = 0.618 - 0.000035 Speed + 0.000132 Feed + 0.00194 Nozzle dia.
2. 80/100 = 0.303 - 0.000035 Speed + 0.000132 Feed + 0.00194 Nozzle dia.

For this model R^2 value = 91.56%, R^2 (adj) = 90.47% this indicate that the model is desirable and 90.47 % variability is explained by the model after considering significant parameters.

Ra value = 0.303 - 0.000035 *800 + 0.000132 *600 + 0.00194 *5

= 0.3639 µm

7. CONCLUSION

Experiments are conducted by using optimal level for each parameter. Table 7.1 shows the comparison of the predicted and the actual responses obtained during experimental trial.

The predicated and actually measured response for surface roughness is in good agreement, indicating that optimization of the control parameters was appropriate.

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