iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 Issue: II Month of publication: February 2016

DOI:

www.ijraset.com

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Volume 4 Issue II, February 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Effect of Shot Peening Parameters on Almen Intensity

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Abstract - Shot peening is a cold working process with many input variables. The material responses include residual stresses, surface hardness, surface roughness, micro-cracks and micro-structure changes. In practice, Almen strip is kept along with the part to be shot peened and is subjected to the same peening conditions. In this investigation, experiments were designed using the Taguchi's Orthogonal Array technique. A centrifugal type of shot peening machine is used for shot peening. Effects simultaneous variation of process parameters such as shot size, shot flow rate, Work height, and Exposure time on Almen intensity was investigated. An ANOVA was carried out to identify the significant peening parameters.
Index Terms – shot peening, almen intensity,taguchi

I. INTRODUCTION

Shot peening (SP) is a cold-working process that hardens the surface of a metallic component by bombarding it with a stream of small particles called shots. SP is viewed as a process involving multiple and progressively repeated impact. The indentation at each point of impact is the result of local plastic deformation [1]. Shot peening is nowadays used with hundreds of different components like railway and automobile leaf springs, helical springs of all types, gears, axle bearings, crankshafts, pneumatic drills, milling cutters, connecting rods, coil springs, cylinder blocks, valve springs [2]. Shot peening modifies the metallurgical, mechanical aspects of peened material such as microhardness, residual stresses, depth of plastic deformation and surface roughness[3]. Shot peening is widely used to improve the fatigue properties of components and structures. Residual stresses, surface roughness and work hardening are the main effects induced in the superficial layer from shot peening, which depend on the correct choice of the peening parameters[4].

The intensity of peening operation is dependent upon several factors which determine how much energy is transferred from shot to the work piece. In order to obtain optimum improvement in fatigue properties, it is important to peen at the correct intensity and consequently accurate measurement of the intensity is necessary.

Generally, Three types of Almen strips, N, A and C are used. The length and width of all these strips are the same but their thicknesses are different. Generally, N type strip is used for low intensity applications, while A and C type strips are used for medium and high intensity applications[3].

In the actual process carried out in the industrial environment, all parameters are varied simultaneously. The effect of simultaneous variation of the process parameters such as shot size, shot flow rate, exposure time and work height on Almen intensity of A type strip is reported here.In this paper an approach based on the Taguchi methodology is used as an efficient method to determine the main factor effects as well as level of significance of each parameter.

II. EXPERIMENTAL WORK

A. Shot Peening System

In the present study centrifugal shot peening system is used. In this system, shot is fed to the center of the wheel rotating at high speed where it is flung out along the blades radiating from the center to strike the work piece. The wheel is of 305 mm diameter rotating at 2410 rpm, which is belt driven through a motor operating at 1490 rpm.

B. Selection of Parameters And Their Levels

In the centrifugal system it is observed that wheel speed, shot flow rate, shot type and shot size, time of exposure, work height could be the various factors which will influence the amount of shot peening done on work piece and its resulting effects significantly. In the centrifugal system under study it is found that wheel speed is not adjustable because it is operating at fixed

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ISSN: 2321-9653

speed of 2410 rpm. So it is decided to investigate the effect of remaining parameters of the system i.e. Type and shot size, shot flow rate, work height , time of exposure by setting these parameters at 2 distinct levels. Quantity of shots needed and the cost associated with experiments was the main reason to restrict the study upto 2 levels.

C. Experimental Layout

The important thing to conduct the experiment is to have proper layout of the experimental runs. Statistical software MINITAB 16 was used for the appropriate selection of orthogonal array as an experimental layout. Since the effect of four factors, shot size, shot flow rate, work height, exposure time has to be studied at 2 levels each; L8 orthogonal array was selected out of the resulted possible orthogonal arrays L8,

Fig. 1 Centrifugal shot peening system used

L12, L16, L32. L16 would have resulted into full factorial experiment. The cost of experimentation and time associated were the constraints. The experimental layout given by MINITAB, after assigning the factors to L8 orthogonal array is as shown in table 3.
Complete randomization within blocks is used where one factor may be very difficult or expensive to change the test setup for, but others are very easy. In the present study, out of the four factors selected shot size is a factor which is very difficult to change for every trial. Because 2 levels were selected for study, one is a mixture of S-230 & S-390 and the second level is of shots S-230 alone. A quantity of around 125-150 kg was needed to be filled in machine for each level and hence very difficult to change for every trial, if complete randomization would have been selected. Hence it was decided to select the complete randomization within the blocks.

Table 1 Parameter levels and their values

Parameters	Level 1	Level 2
Shot size	S-230 and S-390	S-230
Shot flow rate (kg/min)	11.5	25
Work height (mm)`	180	240
Exposure Time(min)	2	4

Table 2 Experimental layout after assigning parameters to L8 orthogonal array

Volume 4 Issue II, February 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

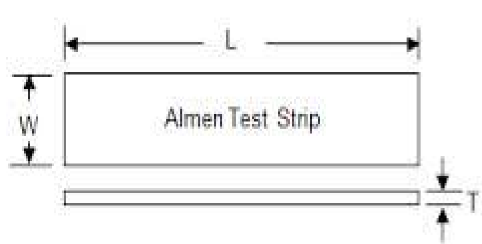
Trial Number	Shot Size	Shot flow rate	Work height	Exposure time
1	S-230+S-390	11.5	180	2
2	S-230+S-390	11.5	240	4
3	S-230+S-390	25	180	4
4	S-230+S-390	25	240	2
5	S-230	11.5	180	4
6	S-230	11.5	240	2
7	S-230	25	180	2
8	S-230	25	240	4

Table 3 Experimental runs after randomization

Run No.	L8-trial No.	Shot size	Shot flow rate	Work height	Exposure time
1	2	S-230+S-390	11.5	240	4
2	4	S-230+S-390	25	240	2
3	1	S-230+S-390	11.5	180	2
4	3	S-230+S-390	25	180	4
5	5	S-230	11.5	180	4
6	7	S-230	25	180	2
7	8	S-230	25	240	4
8	6	S-230	11.5	240	2

D. Almen Intensity Measurement

Two Almen strips were used per experimental trial to have an idea about intensity of peening during various trial conditions. Almen strips were mounted on almen strip holder. Almen strips of 'A' type were used and arc height measurement was done by Almen gauge with least count of 0.01 mm. The dimensions and properties of the almen strips used are as shown in table 4.



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ISSN: 2321-9653

Fig. 2 Almen Test strip

Table 4 Properties of Almen strips

Type of strip	a-type
Material	sae 1070
Flatness	+/- 0.0025 mm
Hardness	hrc 44-50
Dimensions	l= 76 mm W= 18.957 mm T= 1.288 mm

The almen intensity readings for shot peened specimens of all experimental trials are indicated in table5.

Table 5 Almen intensity readings

Trial No	Replication1	Replication 2	Average (mm)
1	0.27	0.28	0.275
2	0.32	0.33	0.325
3	0.52	0.51	0.515
4	0.49	0.52	0.505
5	0.42	0.40	0.41
6	0.35	0.33	0.34
7	0.45	0.46	0.455
8	0.39	0.4	0.395

The average value of each experimental trial is used for further analysis.

III. ANALYSIS AND RESULTS

A. ANOVA

The final phase of DOE process is to analyse and interpret the experimental results. Analysis of variance (ANOVA) is predominant statistical method used to interpret experimental data and make the necessary decisions since this method is most objective.

The results obtained for Almen intensity by the design of experiments were analysed to draw the meaningful inferences. Analysis of variance was performed with the help of MINITAB16 (statistical software), to judge which of the factors in experiments are statistically significant The ANOVA table and response table for means from MINITAB are shown in table 6 and table 7 respectively. The F-ratio from the table can be used to determine which factors have a significant effect on response. The F_{data} = 6.06 for the factor 'Shot flow rate' from ANOVA table, whereas $F_{0.1,1,3}$= 5.54 from the table at 90% confidence. Since F_{data}> $F_{0.1,1,3}$ Shot flow-rate is a significant factor for response (Almen intensity) at 90% confidence level. However the factors 'shot size', 'Work height' and 'exposure time' are not statistically significantly related to response.

It can be clearly seen from the ANOVA table that, 'Shot flow rate' is most dominating factor, next dominating factor is 'shot size', followed by 'exposure time' and least significant
is ' work height'.

Table 6 The ANOVA table

Volume 4 Issue II, February 2016
ISSN: 2321-9653

Factor	Degree of freedom (f)	Sum of Squares (SS)	Variance	F-ratio	p-value
Shot size	1	0.000050	0.000050	0.01	0.931
Shot flow rate	1	0.033800	0.033800	6.06	0.091
Work height	1	0.001012	0.001012	0.18	0.699
Exposure time	1	0.000612	0.000612	0.11	0.762
Residual Error	3	0.016725	0.005575		
Total	7	0.052200			

Table 7 Response table for means from MINITAB

Level	Shotsize	Shot flowrate	Work height	Exposure time
1	0.4050	0.3375	0.4138	0.3938
2	0.4000	0.4675	0.3913	0.4113
Delta	0.0050	0.1300	0.0225	0.0175
Rank	4	1	2	3

Referring to the guidelines of MINITAB software to analyse the results, it is suggested to use P-value from ANOVA table to determine which factors in the model are significant. The P-value for each factor is compared to selected α-level. While comparing the F-ratios we compared them at 90 % confidence level, that is α-level selected is 0.1. Since the p-value for shot flowrate is 0.091(< 0.1). it is statistically significant parameter at 90% confidence level.

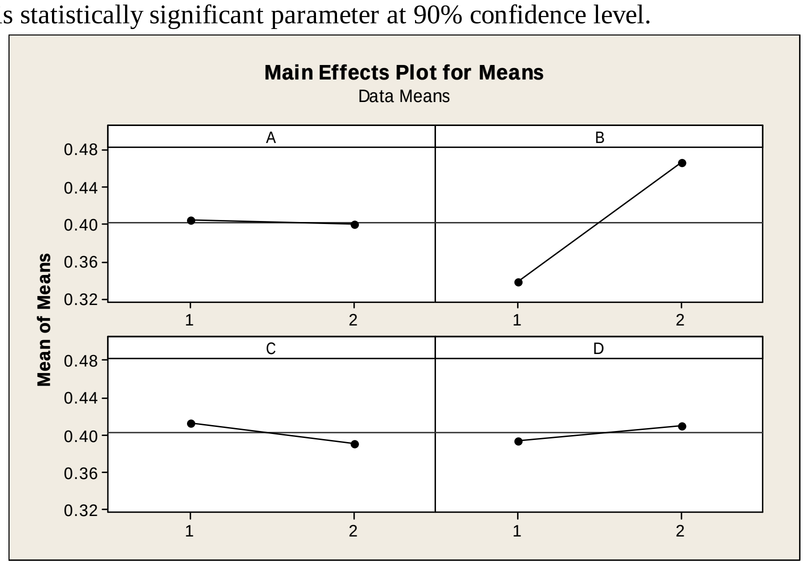

Fig.3 Main effects plot for Means of Almen intensity

Volume 4 Issue II, February 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

The main effects plot is obtained from MINITAB 16. After analyzing main effects plot it is advisable to set shot size and work height at level 1 whereas shot flowrate and exposure time at level 2 to maximize the Almen intensity.

B. Confirmation Experiment

A confirmation experiment is performed by conducting a test using a specific combination of the factors and levels previously evaluated. The sample size of confirmation experiment is larger than the sample size of any specific trial in the previous factorial experiment. The purpose of confirmation experiment is to validate the conclusions drawn during the analysis phase[5].

Referring to the analysis, shot flow rate was identified significant factors for response (Almen intensity). Since for Almen intensity higher average response is better (higher-is-better), the preferred level of the factor shot flow rate is obtained from response table for means. Level 2 (25 kg/min) of shot flow rate is selected as preferred levels for this factor because it give the higher average response as compared to their other level. Since Work height , shot size and exposure time are insignificant factors for Almen intensity response, work height is set at 180 mm , shot size at S-230+S-390 and exposure time was kept 4 min during confirmation experiment.

Table 8. Almen intensity Data from confirmation Experiments

Sample No	1	2	3	4	5	Avg
Almen intensity(mm)	0.47	0.43	0.475	0.515	0.5	0.478

The estimated mean response for Almen intensity with selected factor level combination is 0.49 with confidence interval calculated as 0.15. Therefore it is expected to have average of the results of confirmation experiment to be within 0.33 and 0.64 mm. As the Almen intensity of the confirmation experiment 0.478 VHN falls within the confidence interval estimated, it validates the determination of statistically significant factors and their selection for conducting confirmation experiments.

IV. RESULTS AND DISCUSSIONS

Shot flow rate was the statistically significant parameter for selected factor levels in experimentation, as indicated in ANOVA for almen intensity. Considering cost and time for experimentation , study was restricated only for main factors effect using L8 array.However interaction effects can be studied in detail using full factorial experiment and more levels.

V. ACKNOWLEDGMENT

The authors are pleased to acknowledge Hi Tech enterprise, chinchwad pune for allowing to work on centrifugal shot peening machine available in their company premises.

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