Experimental Analysis of Shot Peening Parameters on EN9

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Abstract— Engineering components and structures are regularly subjected to alternating loads, which made them prone to fatigue failures. It is well known fact that almost all fatigue cracks form at surface due to variety of surface stress concentration features, including grain boundaries, machining marks, surface breaking inclusions. Fatigue performance of metallic parts depends on three factors: Metallurgical, surface geometry and residual stress. The residual stresses are mainly of two types i.e. tensile residual stresses and compressive residual stresses. Tensile residual stresses are responsible for detrimental effects on the component and compressive residual stresses for beneficial effects on the components. The shot peening is the process by which the compressive residual are induced in the component and that increases surface hardness which can be helpful to avoid the fatigue failure of the component. The performance of the shot peening can be measured by the Arc height and the Almen Intensity. The experimental study made with the help of RSM and validation by the regression and ANOVA of shot peening process on the chain link used in the conveyors.

Key words: Shot Peening, Residual Stresses, Fatigue Failure, RSM, Regression, ANOVA

I. INTRODUCTION

Engineering components and structures are regularly subjected to alternating loads, which made them prone to fatigue failures. It is well known fact that almost all fatigue cracks form at surface due to variety of surface stress concentration features, including grain boundaries, machining marks, surface breaking inclusions. Fatigue performance of metallic parts depends on three factors: Metallurgical, surface geometry and residual stress. Performance can also been affected by damages during process manufacturing or in service. Shot peening is a cold working process improving the mechanical properties such as fatigue, stress corrosion cracking, and so on. Shot peening has potentially positive and sometimes negative effects on all these factors. Creation of compressive residual stress, work hardening, surface roughness and tribological properties modification, delay of micro grain propagation in service. Numerous investigations in the past have shown that shot peening can improve the fatigue performance of structural materials such as steels and aluminum alloys. Therefore in shot peening different parameters used and that are controlled depending upon experimentation made by different experimentation techniques .There are no of shot peening input parameters are used such as Shot nature, shot size, shot hardness, Almen intensity, shot angle, coverage, distance between blower and work piece, nozzle diameter , shot material , type of shot peening machine , material of specimen, density of shots, composition of shots, peening medium, pressure of compressed air

The control of residual stress is crucial in ensuring the integrity of engineering components and shot peening can be used to good effect to introduce the beneficial compressive residual stress levels required. Therefore to have good results from shot peening the ideal conditions required for the performance of controlled shot peening.

II. THE ORIGIN OF STRESSES

Residual stresses can arise in materials in almost every step of processing. The origins of residual stresses in a component may be classified as: mechanical, thermal, and chemical. Mechanically generated residual stresses are often a result of manufacturing processes that produce non-uniform plastic deformation. They may develop naturally during processing or treatment, or may be introduced deliberately to develop a particular stress profile in a component. Examples of operations that produce undesirable surface tensile stresses or residual stress gradients are rod or wire drawing, welding, machining and grinding. Fig. shows characteristic residual stress profiles resulting from different types of grinding. It can be seen that conventional and highly abrasive grinding produced tensile stresses near the surface compared with compressive stresses with gentle grinding. Compressive residual stresses usually lead to performance benefits and can be introduced by shot peening, toughening of glass or cold expansion of holes. On a macroscopic level, thermally generated residual stresses are often the consequence of non-uniform heating or cooling operations. Coupled with the material constraints in the bulk of a large component this can lead to severe thermal gradients and the development of large internal stresses. An example is the quenching of steel or aluminum alloys, which leads to surface compressive stresses, balanced by tensile stresses in the bulk of the component.

A. Importance of Residual Stress

Residual stress affects:

- Low cycle and high cycle fatigue performance
- Distortion
- Peen forming (controlled distortion)
- Fretting
- Stress corrosion cracking (SCC) and hydrogen initiated cracking (HIC)
- Crack initiation and propagation. (Damage tolerance)
- Residual Stress distribution is rarely as assumed in FE models and or fracture mechanics; real data is necessary to improve the accuracy and effectiveness of the modeling.

B. The Benefits of Measuring and Monitoring Residual Stresses

- Optimize process parameters, such as measuring the effectiveness of penning on part critical locations.
- Provide a quantitative metric to enable specifications and Go/No-Go decisions.
- Improve product quality; substantiate supplier quality, engineering source approval (ESA)
- Improve safety and reduce catastrophic failures.

- Extend component or structure life by ensuring sufficient compressive residual stress is present.
- Validate repair area has been "restored" to original specifications.
- More accurate replacement part requirements by tracking residual stress degradation; thus, enabling retirement for quantitative cause. Residual stress information can improve the probability of detection of other nondestructive techniques.

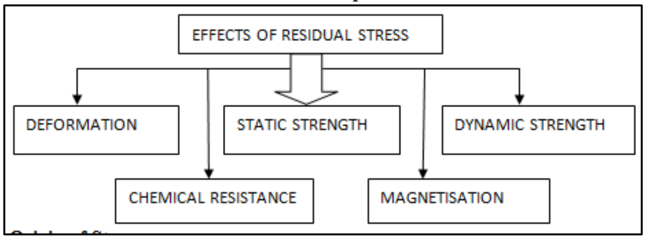

Fig. 1: Probability of detection of other nondestructive techniques

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F. Detrimental and favorable influence of Residual Stresses

Residual stresses in a work piece are function of its material processing and machining history residual stresses can enhance or impair functional behavior of a machined part. Economical and technical aspects require better utilization and higher loading of machines and plants and their components .thus methods of projection and design have to be improved .the physical state of high duty work pieces has to be described precisely. This includes the knowledge of residual stresses in the component and especially in its surface layers the machining process which generates the functionally relevant surfaces of components has great importance for the development of the physical state of the surface and the residual Stress distribution in it. For many applications the properties of a parts surface are dominant for the functional behavior of the whole component.

G. Controlled Shot Peening an Overview

Controlled shot peening process is the most cost effective and practical method of inducing surface residual compressive stresses which enhance the performance and extend the life of critical components. Component failure is often related to residual tensile stress induced during manufacturing. Each shot striking the metal acts as a tiny peening hammer imparting a small indentation or dimple into the surface

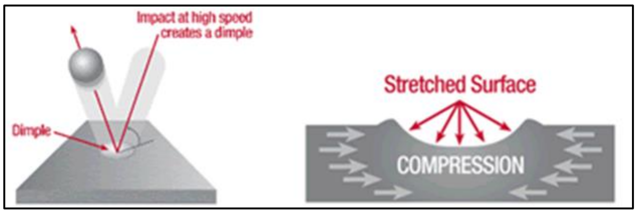

Fig. 2: Controlled Shot Peening Process

III. THE PERFORMANCE OF THE SHOT PEENING IS MEASURED BY ARC HEIGHT AND ALMEN INTENSITY

The efficiency and the performance of the shot peening is important to get calculated to set the parameters for the different manufacturing processes. The following are the components of the process of the shot peening performance evaluation.

A. Arc Height

Zero the Almen gage using the flat side of the calibration block. Place the Almen strip on the gage firmly seated on the four support balls with the non-peened side touching the indicator stem. The new reading on the indicator is the arc height. Record this value in a table and on the graph for saturation curve. Do not re-use an Almen strip. A new strip must be used for each data point of the saturation curve. Repeat the above process using increasingly longer exposure times.

B. Almen Strip

It is a metallic strip which is precisely manufactured under the controlled environmental conditions. There are three types of the Almen Strips

- 'N' = .032" for low intensity
- 'A' = .051" for medium intensity (range 6A to 24A)
- 'C' = .094" for high intensity

C. Almen Intensity

The shot peening intensity is defined as the arc height of an Almen test strip measured at coverage of 98 % by using an almen gauge. An almen strip after shot peening gets a curvature the n that strip is measured by an Almen gauge following are the Almen gauge and the procedure of Almen Intensity measurement

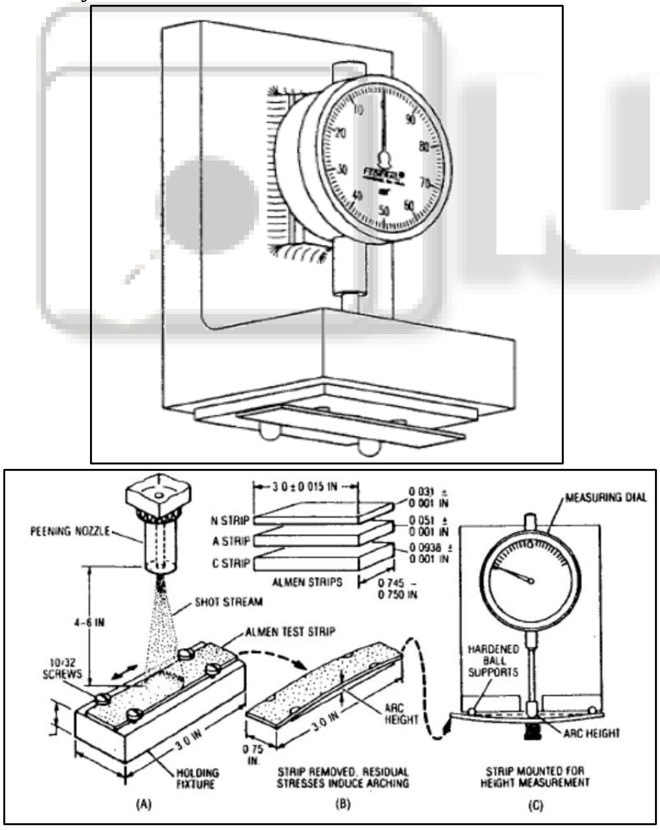

Fig. 3: Shot Peening Intensity

IV. PRE EXPERIMENTATION WORK

A chain link used in conveyor is having several issues regarding its fatigue strength and the fatigue failure. The fatigue failure caused by many problems but out of that improper microstructure and internal cracks due to the primary manufacturing processes like forging, shearing etc. are identified from the research study. The I/P parameters selected depending upon the availability are standoff distance(30cm-60cm), velocity of shots (40m/s-60m/s) and time of peening(120sec-180sec). The chemical composition of the material is C-0.520%, Mn-0.80%, Cr-0.21%, Ni0.06%, Mo-0.021%, S-0.027%, P-0.024%, Si-0.35%. DoE is carried out in RSM by CCD.

V. EXPERIMENTATION

After performing the shot peening on the components the arc height of each sample is measured and corresponding Almen Intensity is calculated. Depending upon the same information the following table has been prepared.

Standoff Distance	Time of Peening	Velocity of Peening	Almen Intensity	Arc Height
50	120	60	6.7878	0.54
40	150	50	6.7878	0.54
40	150	50	6.5364	0.52
40	150	50	5.9079	0.47
30	180	40	5.2794	0.42
40	150	50	5.7822	0.46
50	180	40	5.2794	0.42
30	180	60	7.2906	0.58
50	120	40	5.2794	0.42
40	99.546	50	5.7822	0.46
23.1821	150	50	5.6565	0.45
40	200.454	50	5.6565	0.45
50	180	60	6.7878	0.54
40	150	50	5.6565	0.45
30	120	60	7.542	0.6
40	150	50	5.4051	0.43
56.8179	150	50	5.4051	0.43
30	120	40	5.4051	0.43
40	150	66.8179	7.7934	0.62
40	150	33.1821	5.2794	0.42

Table 1: DoE & Response Table

From the above results it is clear that as velocity of the shots increases and the standoff distance decreases the arc height and corresponding Almen Intensity increases and as the velocity decreases the arc height and corresponding Almen Intensity decreases.

VI. OPTIMIZATION IN RSM GIVES THE ADEQUACY AND ANOVA FOR ARC HEIGHT

A. Adequacy of the Model for Arc Height

The analysis was done using uncoded units

Arc Height (AH) = 0.282135-0.009744 SD-0.000762 V-0.007715 TP.

Term	Coef	SE Coef	T	P
Constant	0.282135	0.583945	0.483	0.639
Standoff (SD)Distance	0.009744	0.011066	0.881	0.399
Velocity of Shots(V)	0.000762	0.003917	0.195	0.850

Time of Peening(TP)	-0.007715	0.011750	-0.657	0.526
S= 0.03373 R-Sq= 86.1 % R-Sq(adj)=73.6				

Table 2: Coefficient Table for Arc Height

Source	DF	Seq SS	AdjSS	Adj MS	F	P	
Regression	9	0.070400	0.070400	0.007822	6.88	0.003	Significant
Linear	3	0.061823	0.001905	0.000635	0.56	0.655	Not Significant
Square	3	0.007439	0.007439	0.002480	2.18	0.154	Not Significant
Interaction	3	0.001137	0.001137	0.000379	0.33	0.802	Not significant
Residual Error	10	0.011375	0.011375	0.001138			
Lack-of-Fit	5	0.002292	0.002292	0.000458	0.25	0.922	
Pure Error	5	0.009083	0.009083	0.001817			
Total	19	0.081775					

Table 3: ANOVA Table for Model of AH

From ANOVA Table it is clear that p value is less than 0.05 that shows it is significant. The residual plots for Arc height shows the linearity and the other effect of the parameters on the process and its significance.

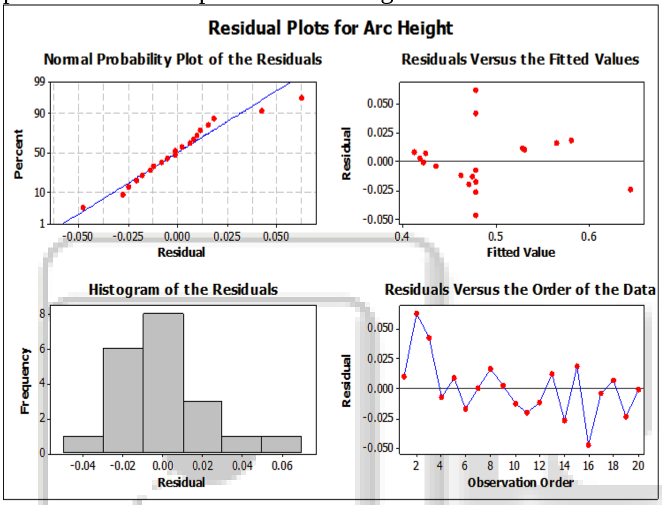

Fig. 4: Residual Plot for Arc Height

VII. Conclusion

From the experimentation it is clear that velocity of the shots and the standoff distance are the significant parameters of the shot peening. Arc height measurement is an effective technique to measure the performance efficiency of the shot peening process and so the Almen Intensity.

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