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Correlation between Mechanical and Geometrical Characteristics of Shot and Residual Stress Induced by Shot Peening

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1 Abstract

Accurate measurement of induced residual stress is necessary in order to evaluate the validity of peening process parameters. Among these parameters, a fundamental role is played by size and hardness of shot. Both of these characteristics are governed by specifications. Another important aspect is the use of "conditioned" shot.

The scope of our analysis is to verify if it is possible to achieve greater process repeatability and reliability by using shot with a narrower hardness range and with more precise geometrical characteristics, compared to values found in current specifications. We have therefore measured surface and in-depth residual stress by X-ray diffraction and have analyzed the shape of the shot with a scanning electron microscope (SEM). We have also evaluated the effect on both conditioned and non conditioned shot following impact on the peening surface by SEM analysis.

2 Introduction

Increase in resistance to fatigue induced by shot peening is a result of surface compression. This surface compression is caused by the transfer of part of the kinetic energy of the shot to plastic deformation energy in the peened surface. Obviously, the percentage of energy transferred from kinetic to plastic deformation is a function of the geometric parameters of the impact which takes place between the shot and the peened surface. The most important geometric parameters are the angle of impact and obviously, the shot size. However, the exchange of energy between shot and surface is also influenced by other parameters, such as for example, the hardness and the shape of the shot. Peening shot is characterized by a nominal diameter (or size). The distribution of size around a nominal value is determined by SAE AMS-S-13165. Hardness values are also specified in SAE AMS 2431/1 and 2431/2. For this study, we have used grain size distributions and hardness ranges which are narrower than those contemplated by the abovementioned specifications. Furthermore, we have used shot which has been "conditioned", i.e. shot which has been through a sort of preliminary peening process which eliminates shot with structural defects (hollows or excessive porosity) even though they are within limits imposed by the specifications. The conditioning of three test batches (nos. 1, 3 and 4) was done at 40 cycles. The fourth batch (no. 2) was unconditioned.

3 Test Parameters

Four different types of shot were used for the peening tests, as follows:

Table 1: Type 1 ASH 330 conditioned

Characteristics	
Grain Sizes (mm)	Test results (%)
>1.180	0
>1.000	0.3
>0.850	91
>0.710	100
Chemical Analysis	
Elements	Percentage
C	0.93
Mn	0.65
Si	0.61
P	0.025
S	0.024
Hardness HRC	
Average	61.1
Minimum	60.0
Maximum	62.0
In range	100

Table 2: Type 2 ASH 330 unconditioned

Characteristics	
Grain Sizes (mm)	Test Results (%)
>1.400	0
>1.180	0.1
>1.000	27
>0.850	97
>0.710	100
Chemical Analysis	
Elements	Percentage
C	0.97
Mn	0.68
Si	0.66
P	0.016
S	0.024
Hardness HRC	
Average	59.6
Minimum	58.0
Maximum	62.0
In range	100

Table 3: Type 3 ASH 330 conditioned

Characteristics	
Grain Sizes (mm)	Test Results (%)
>1.400	0
>1.180	0.1
>1.000	27
>0.850	96
>0.710	100
Chemical Analysis	
Elements	Percentage
C	0.95
Mn	0.65
Si	0.65
P	0.021
S	0.025
Hardness HRC	
Average	61.3
Minimum	60.0
Maximum	63.0
In range	95

Table 4: Type 4 ASH 330 conditioned

Characteristics	
Grain Sizes (mm)	Test Results (%)
>1.400	0
>1.180	0.1
>1.000	24
>0.850	96
>0.710	100
Chemical Analysis	
Elements	Percentage
C	0.96
Mn	0.63
Si	0.60
P	0.0185
S	0.023
Hardness HRC	
Average	60.3
Minimum	58.3
Maximum	62.0
In range	100

The peening test pieces are made of casehardened steel type 18NiCrMo7 (depth of casehardening 1 mm) and hardened to 850 HV.

The following are images of unconditioned and conditioned shot taken with an SEM:

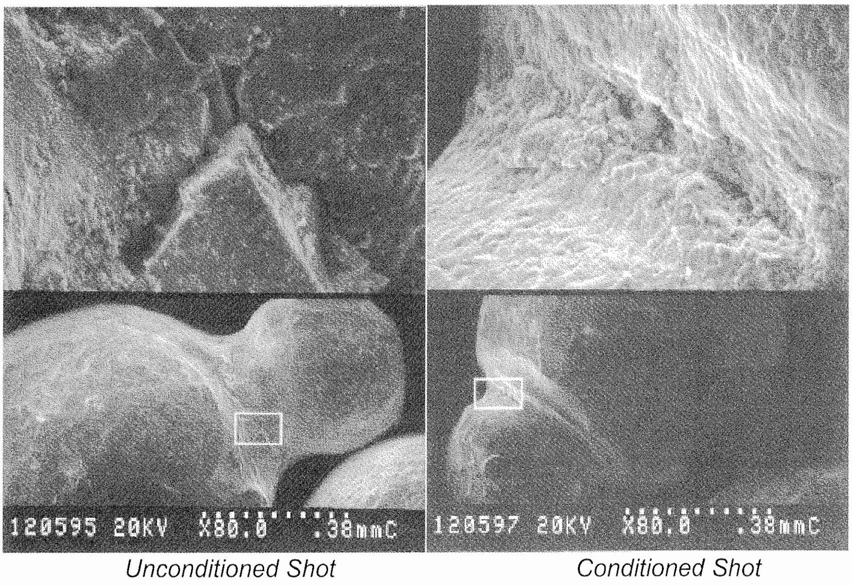

Figure 1: Unconditioned shot and conditioned shot

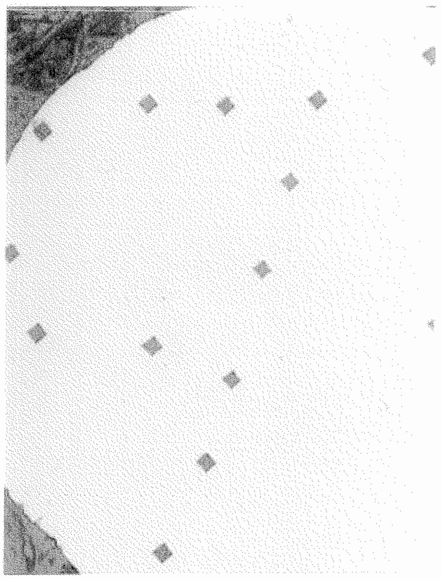

Figure 2: Vickers microhardness indentations on a conditioned shot particle

4 Results

Peening was done by a robot system with the same parameters for all four shot types:

- intensity 14 Almen A
- coverage 150%

Residual stress was measured by X-ray diffraction [1] and gave the following results:

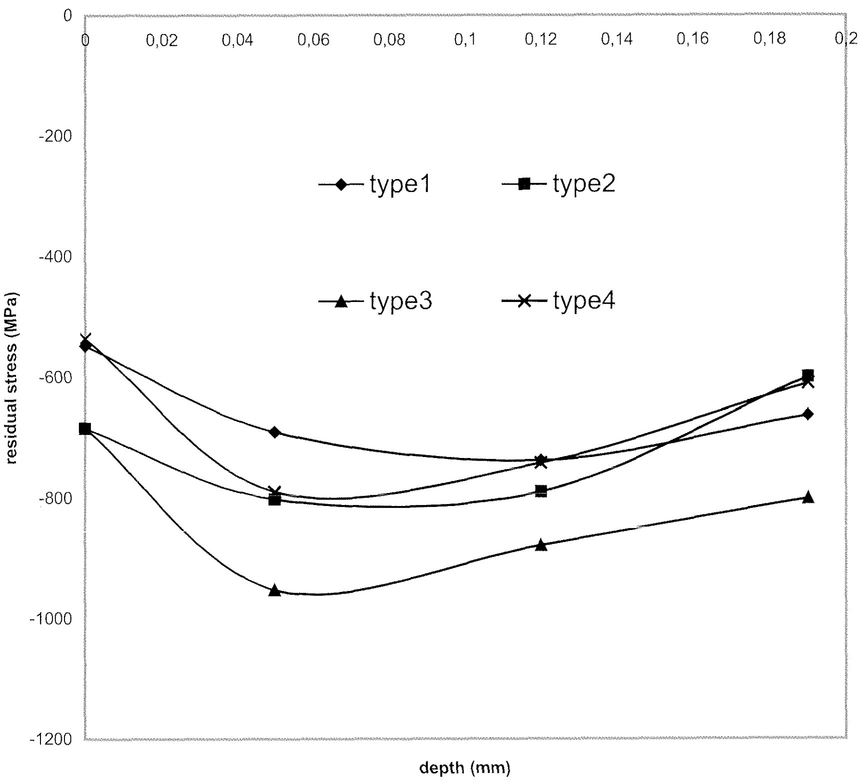

Figure 3: Residual stress results

5 Conclusions

SEM images taken before the peening application show how conditioning eliminates imperfections (e.g. cracks) which would otherwise lead to premature breaking up of shot. This ensures a more consistent level of grain size distribution. It is interesting to note in these images the plastic deformation of shot particles after impact.

Our conclusions must necessarily take into account the type of shot and the conditioning values used for this test. The fact that the hardness level before conditioning was already quite high (almost 60 HRC) means that conditioning produces less of a hardening effect than if the initial hardness level had been, say, 45 or 50 HRC. In addition, the number of cycles, speed and mass of shot have a direct influence on the hardening effect of conditioning. For these reasons the conditioning process carried out for this test at the abovementioned parameters and on shot with the abovementioned characteristics had no significant effect on hardness levels, as was verified by microindentation hardness tests. Separate tests have been carried out to verify the effect on hardening and on transmitted energy with test parameters different from the ones used for this test.

Induced residual stress was not influenced in any significant way by conditioning of shot with a wide hardness range. In fact, shot types 2 and 4 induced approximately the same in-depth residual stress profile, even though they generated different residual stresses at the surface.

On the other hand, conditioning appears to have had a greater effect on shot with narrower hardness ranges and with narrower grain size distributions than those required by the specifications (types 1 and 3).

6 References

[1] TAIRA S., "X-ray studies on mechanical behavior of materials". The Society of Material Science, Japan, 1974, pp. 22–32.