INFLUENCE OF AGEING OF A CUT STEEL WIRE SHOT DURING SHOT PEENING

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ABSTRACT

Cut steel wire shot is often used for shot peening treatments. A CW32 shot was used in this study. Surface roughness and produced residual stresses were checked during the shot peening process in order to determine the influence of ageing, wear, evolution of diameter, scattering of hardness and modification of the shots. The breaking and wearing modes have also been studied.

The results obtained show the good quality of this type of shot for shot peening, in comparison with cast steel shots, provided that the cut steel wire shot has been submitted to prior light shot peening before use (prior conditioning).

KEYWORDS

Ageing, cut steel, residual stress, number of shot peening cycles breakage rate, shot hardness.

1 - EXPERIMENTAL PROGRAM

Cut steel wire shot must undergo a prior conditioning before being used for prestressing. This shot peening "ages" the shot according to the number of shot peening cycles.

This report is an account of the experimental program used to determine the possibilities for use of preconditioned cut steel wire shot in prestressing operations. The tests carried out are especially intended to determine:

- the efficiency of conditioned cut steel wire shot for the prestressing work required
- the wear resistance of this type of shot
- modifications in quality (microstructure, hardness, faults, shape, etc.) over shot service life.

This study was carried out in collaboration with the Metal Improvement Company (Montargis France) on behalf of the Nuove Trafilerie de Valmadrera wireworks (Italy).*

2 - SHOT STUDIED

The shot used in this study is a conditioned cut steel wire shot with the following characteristics:

Shot specification:	CW32
Nominal average diameter:	0.8 mm
Initial wire diameter:	0.8 mm
Weight of 50 shot:	0.16 g
Average hardness:	53 HRC
Carbon content:	0.70%

3 - TEST PROGRAM

To study ageing of shot during prestressing shot peening, a batch of shot was used in a machine. Samples were taken at regular intervals to check:

- grain size
- shape
- internal structure
- hardness
- metallurgical structure and faults, if any.

In addition, to study the influence of aging on shot efficiency, we periodically prestressed samples of 42CD4 steel, hardness 50 HRC, to measure the surface roughness and residual stress.

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4 - SHOT AGEING CONDITIONS

A load of 175 kg of shot was studied in a drum type turbine machine, using pinions treated for 62HRC as "anvils". The shot peening intensity applied for this shot ageing operation was F 45-50A (0.45 to 0.50 mm on the ALMEN A gage). Shot samples were taken after 10, 20, 40, 60, 80, 100, 200, 500 and 1000 cycles. Each cycle lasted 2 minutes, which was the time necessary for the entire load of shot to be used.

5 - MODIFICATIONS IN QUALITY OF SHOT DURING SHOT PEENING

5-1 Grain Size and Breakage Rate

Grain size is determined by taking regular samples of shot and measuring the percentage by weight of shot retained by standardized screens. These values are given in percentage in the table 1.

The percentage of shot retained by the 0.710-mm screen increases noticeably up to 200 cycles after conditioning, then the average diameter increases up to 1000 cycles. This may be partially explained by the fact that the shot becomes increasingly spherical, increasing the diameter to slightly above the cylindrical diameter of the same weight. (For an initial wire cylindrical diameter of 0.8 mm, the radius of a sphere of equal material volume should theoretically be 0.92 mm).

The breakage rate could not be determined by these tests, because the machine had a dust removal system which eliminated shot fragments. We can nevertheless assume that the breakage rate is very low.

5-2 Shape and Internal Structure

Figures 1 and 2 show views of the shot during shot peening, obtained by examination with a scanning electron microscope.

New, conditioned shot can be seen to have a particular shape between the original cylinder from the cut wire and the sphere. Dimensions are apparently not isotropic and the diameter of the shot in the longitudinal direction of the original wire appears to be slightly greater than the transversal diameter (Figure 1).

These figures also show the way in which the shape of the initial cylinder changes during shot peening (see the diagram 1 and Figure 2).

The study of the evolution of the shot as a function of the number of shot peening cycles shows that the shot becomes increasingly spherical: the deformation process begun during conditioning continues.

No particular external fault appears on the shot until 1000 cycles, except for the small scales formed gradually by the impact. The shot takes on an "onion-peel" type surface structure. This structure can already be seen on new shot. It is more accentuated once the shot has gone through many shot peening cycles.

Metallographic inspections are made of transversal sections of the shot to inspect the evolution of shot internal structure.

The internal microstructure of the shot is markedly orientated in wire rolling direction.

Observation of the cross-section of shot shaped during shot peening leads to the following conclusions:

- The shot tends to become increasingly spherical as the number of shot peening cycles increases.

- The surface folds already seen during conditioning are still apparent when the shot begins to become spherical. In some cases, these folds are difficult to see and the shot appears to be quite spherical. In other cases, on the contrary, the folds are large and end up by breaking off the shot.

- One particular fault seems to be the lack of transversal cohesion of the wire, which, during conditioning and shot peening, leads to a loss of material and a significant deformation of the shot to fill the hole thus formed. This leads to a hollow shot as indicated in diagram 2.

Finally, after 1000 shot peening cycles, certain internal discohesions appear, which are always structural discohesions of the wire parallel to the rolling direction.

In general, during the 1000 shot peening cycles, the shot tends to become spherical. Surface faults (folds) or internal faults (discohesions) are visible as from the conditioning period and tend to become accentuated, but only for a relatively low proportion of the shot. These internal faults must lead to the shattering of some shot during shot peening. The proportion of broken shot during shot peening must be relatively low. Because of the low breakage rate in the work conditions concerned, the weight loss due to shot breakage could not be quantified.

5-3 Hardness

To study the evolution of shot hardness, microhardness measurements (HV 1kg) were carried out at mid-radius for transversal sections of new shot, then of shot having undergone 10, 500 and 1000 shot peening cycles.

The statistical dispersion curves thus obtained are shown on figure 3. These results were obtained by taking three measurements of 15 shot out of each batch.

Figures 3 and 4 and the table 2 show the evolution of hardness and standard deviation of hardness as a function of the number of shot peening cycles.

These results show that, as could be expected for cut steel wire shot, hardness is very homogeneous. Average hardness for new, conditioned shot is 545 HV. Furthermore, initial dispersion of hardness diminishes during shot peening, which is normal since all shots tend to develop gradually towards the same metallurgical condition. A significant increase in hardness can be seen in the first cycles, which corresponds to work hardening of the material during the first plastic deformation cycles. The hardness then stabilizes, then falls at 1000 cycles (the metal is softened after a very large number of cyclical plastic deformations).

Finally, dispersion of hardness, which was already low to begin with, slightly diminishes during shot peening. This shows that the hardness of this kind of shot remains relatively homogeneous (compared, for example, with cast steel shots).

6 - EVOLUTION OF SHOT EFFICIENCY DURING SHOT PEENING

To study the influence which ageing of the shot may have on its efficiency in prestressing shot peening operations, samples of 42CD4 steel, hardness 50 HRC (ALMEN intensity of F 45-50A and coverage rate of 125%), were subjected to shot peening at various points in the shot ageing process. The roughness and surface condition were measured using the scanning electron microscope. Residual stress was also measured.

6-1 Roughness

The evolution of roughness of shot peened samples as a function of the number of shot peening cycles was examined. No significant change was found when the shot went through up to 1000 cycles (from 2.8 to 3.04 µmRa).

6-2 Surface Condition

Examination, using the electron scanning microscope, of the surface of samples shot peened with shot having undergone various degrees of ageing showed no influence of ageing on the shot, as had already been demonstrated by the roughness measurements. No particular fault was discovered.

6-3 Residual Stresses

Residual stresses was measured on 42CD4 hardened and tempered steel samples (50 HRC). Samples were 20 mm thick with a 40 mm diameter, and were shot peened on each side using new shot and shot having undergone 10, 500 and 1000 cycles. The step-by-step hole drilling method, recently developed by the CETIM (1), was used. This method consists of drilling a hole in the center of a rosette, using a wire strain gage. After each drilling step, the deformation caused by the mechanical compensation of the part is measured. A software package which calculates stress based on deformation can then determine the distribution of residual stress in terms of depth.

The results obtained are shown in Figure 5.

The residual stress profiles introduced by cut steel wire shot (for an ALMEN intensity of F40-45A) appear to comply with that generally obtained with cast steel shot. The prestressed depth is around 0.35 mm. Maximum stress is obtained for shot aged by 10 shot peening cycles, whereas stress levels are lower for new, conditioned shot. Shot which has undergone 1000 cycles has an intermediate stress profile. This shows the influence of shot ageing on the stress levels obtained. As in the case of hardness, the evolution is very clearly evident during the first 10 cycles. After 10 cycles, shot shape and hardness tend to become homogenized and stable, which leads to the intermediate stress profile (Figure 6). Finally, the level of residual stress obtained here is relatively high (maximum level around 1000-1100 MPa).

For purposes of comparison, the residual stress profile obtained on the same 42CD4 steel after shot peening at the same intensity (F40-45A) with a 0.8 mm diameter cast steel shot (hard quality) of hardness 55-62 HRC (MI 330H) and for a coverage rate of 125%, is shown in Figure 5.

This shot gives a stress profile similar to that obtained with conditioned cut steel wire shot. The maximum residual stress is around that obtained with cut steel wire shot aged by 10 cycles. This is perfectly normal since the cast steel shot used here has an average hardness slightly above that of standard cast steel shot. Furthermore, the grain size of these two types of shot is different.

CONCLUSION

Tests carried out on the diameter 0.8 mm conditioned cut steel wire shot (CW32) showed the good geometric and metallurgical stability of this type of shot for a long shot peening period at an ALMEN intensity of F45-50A.

During shot peening, the shot tends to change from an oblong shape to a spherical shape. Hardness remains homogeneous, with even a reduction in standard deviation as a function of the number of shot peening cycles. Hardness increases during the first cycles, then stabilizes.

The detailed study of the evolution of the shot's shape clearly shows how the metal changes shape as it goes from the cylindrical shape of the cut wire to the oblong shape of the conditioned shot and then to the more spherical shapes after a large number of cycles.

For the working conditions selected (F45-50A), the breakage rate after 1000 shot peening cycles is very low and cannot be quantified. Two types of fault appear during shot peening:

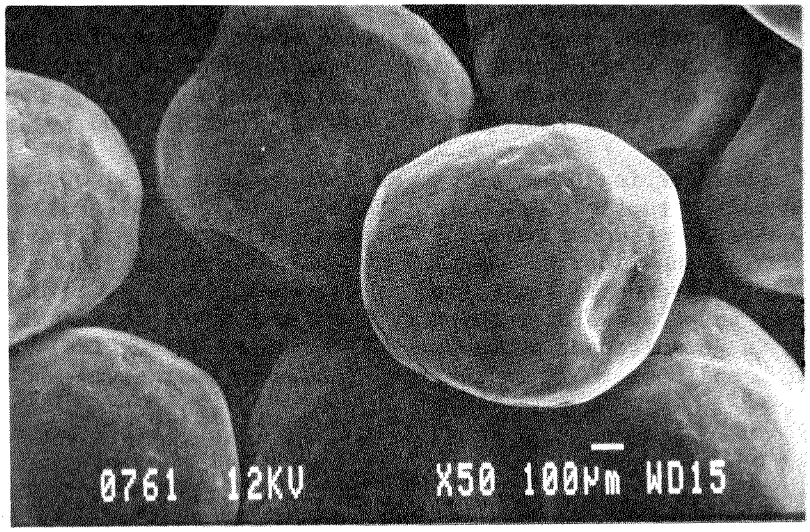
- Folds form on the shot as it changes from a cylindrical shape to a spherical shape. These folds can sometimes break.

- For certain conditioned shot and for a larger quantity of shot after 1000 shot peening cycles, there is transversal discohesion of the shot in the direction of the wire drawing axis. These discohesions can give rise to ejection or abrupt breakage of a portion of the shot. The proportion of shot with this type of fault remains low, even after 1000 cycles.

Ageing of shot during 1000 shot peening cycles does not seem to harm efficiency during shot peening of a 42CD4 steel (45HRC). Roughness of the shot peened part remains constant. The residual stress, on the other hand, changes during the shot peening. This evolution seems linked to that of average shot hardness. The level of residual stress obtained increases considerably as of 10 shot peening cycles (just like hardness, which goes from 545HV in conditioned shot to 564 HV after 10 cycles). This level remains high and comparable to that obtained with cast steel shot.

REFERENCE

(1) LU J., NIKU LARI A., FLAVENOT J.F. "Récents développements de la mesure des contraintes résiduelles par perçage incrémental".
Matériaux et Techniques, December 1985 - pages 709 to 718.



X 50

Figure 1: View of new, conditioned shot

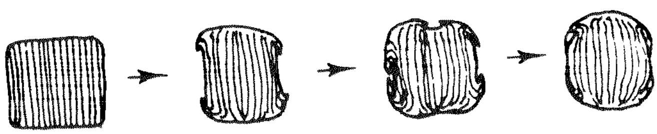
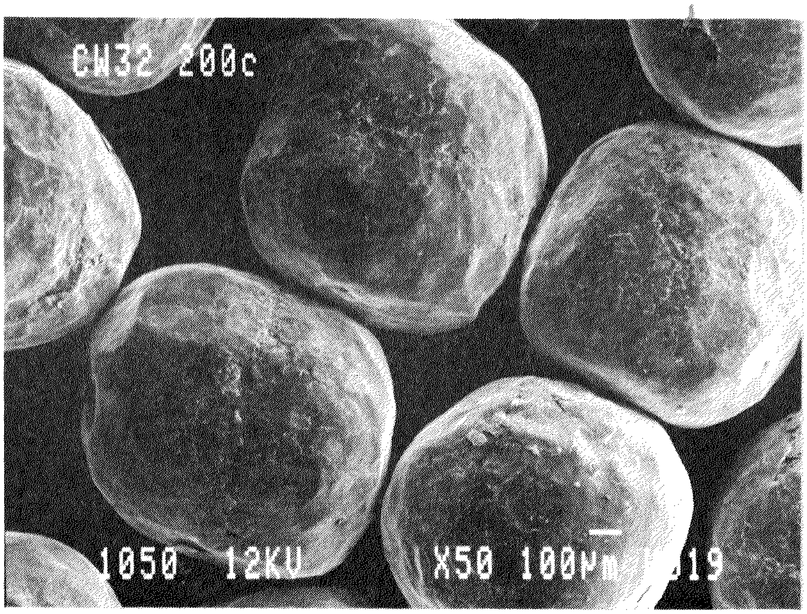


Diagram 1 : Evolution of the shot's shape during shot peening.



X 50

Figure 2 : View of the shots after 200 shot peening cycles

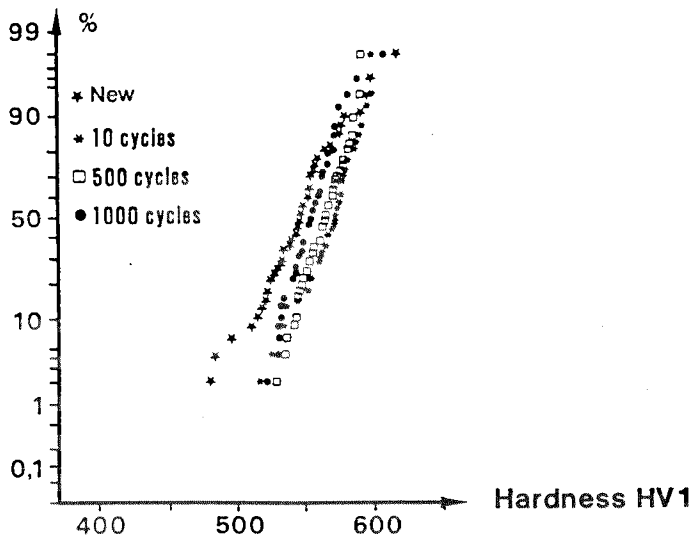


Figure 3 : Evolution of hardness distribution

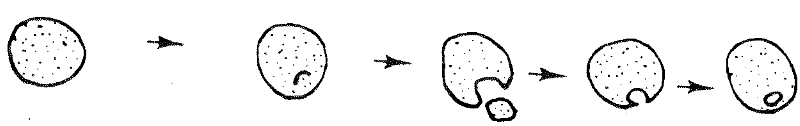


Diagram 2 : Damage mechanism of shot duting shot peening.

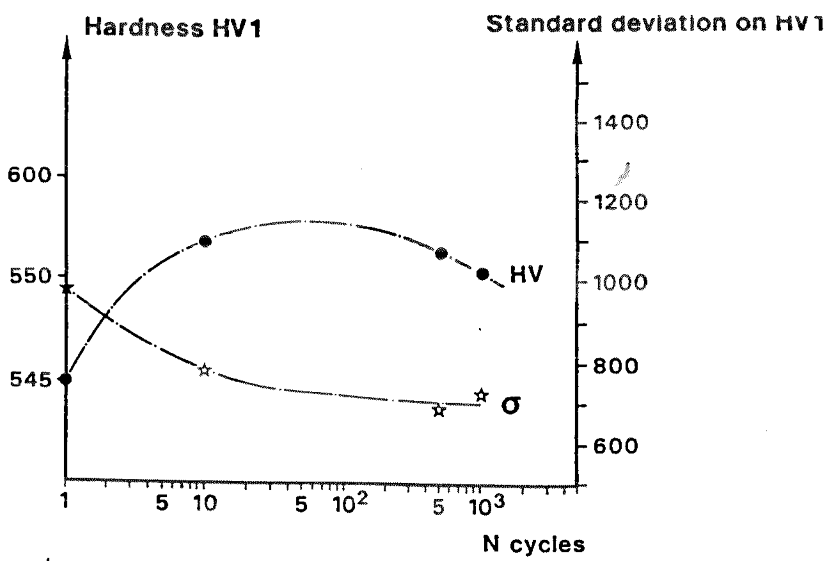


Figure 4 : Evolution of average hardness and standard deviation characteristic of dispersion.

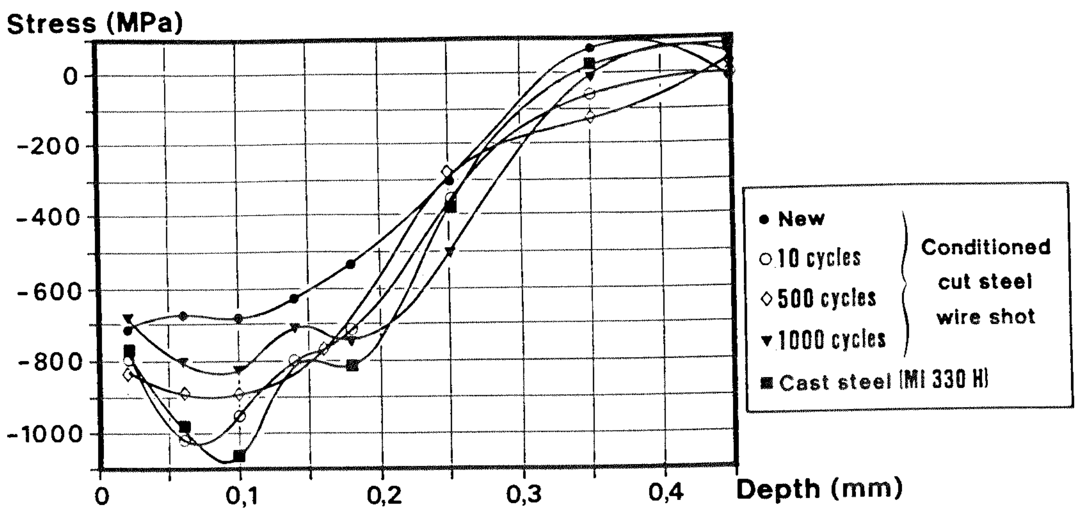


Figure 5: Comparison of residual stress obtained with cut steel wire shot and cast steel shot (MI330H) on a 42CD4 steel (50HRC).

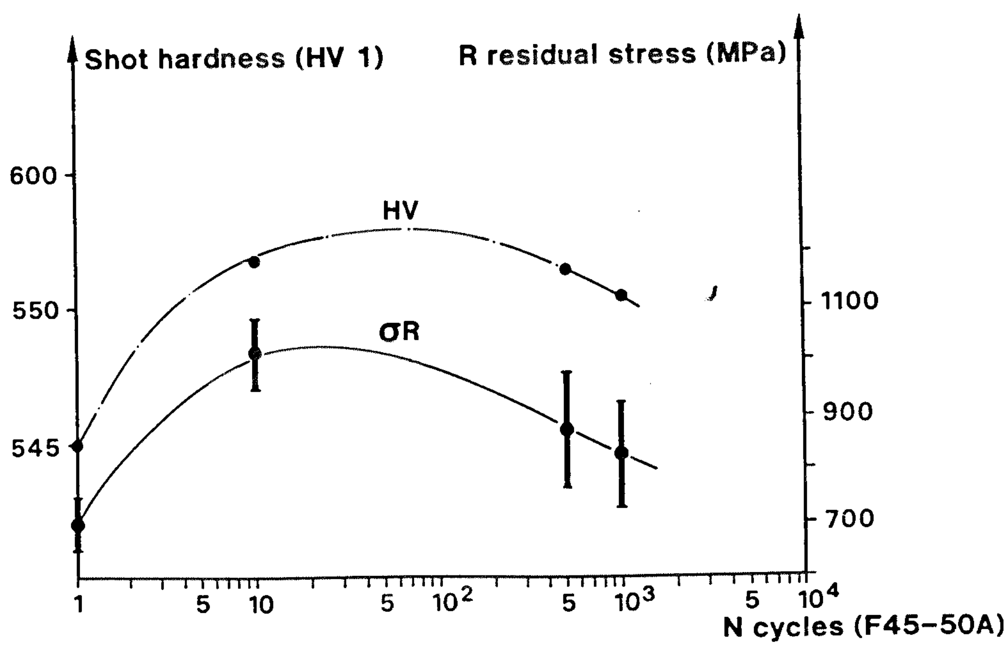


Figure 6: Comparison of evolution of hardness of cut steel wire shot and residual stress introduced in a 42CD4 steel (50HRC)

Number of cycles / Sieve size	0	10	20	40	60	80	100	200	500	1000
1mm	0	-	-	1	-	-	-	-	-	-
0,850	38	30	26	22	17	11	8	4	9	21
0,710	60	68	72	75	83	89	92	96	91	77
0,6	2	2	2	-	-	-	-	-	-	2

Table 1

Shot condition	Average hardness	Standard deviation
New	545	29
10 cycles	564	17
500 cycles	564	17
1000 cycles	554	18

Table 2 : Evolution of average shot hardness