EFFECT OF SHOT PEENING ON PROPERTIES OF CARBONITRIDED CASE WITH RETAINED AUSTENITE

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ABSTRACT

The influence of shot peening on properties of carbonitrided 16 MnCr 5 with high content of retained austenite has been investigated. Changes in technological, structural and physical properties have been determined as a function of shot peening duration at constant shot velocity.

The most striking features, observed after shot peening, are: substantial increase in surface hardness, generation of high compressive stresses, $\gamma \rightarrow \alpha$ phase transformation and increase in half width of α phase.

KEYWORDS

Shot peening; retained austenit; surface hardness; X-ray diffraction; phase transformation; residual stresses; half width.

INTRODUCTION

The structure, usually generated by case hardening, consists mostly of martensite and traces of retained austenite. Owing to its low hardness retained austenite has never had a good reputation in the technology of heat treatment. It has been established (Razim, 1968), however, that the low hardness and the low bending fatigue strength of samples with high content of retained austenite can be increased considerably by shot peening or rolling; even higher than the level achievable only with martensitic structure.

Further investigations (Schreiber and others, 1978a, 1978b, 1978c; Starker and others, 1980) have been conducted on case hardened as well as on hardened and tempered samples after shot peening by variable velocity and coverage. Very little is known, however, on the effect of shot peening for different lengths of time on case structures and their properties. In this work the effect of shot peening duration, particularly on properties of carbonitrided case with high content of retained austenite, has been investigated. Changes in technological, structural and physical properties have been determined on the surface, as a function of short peening duration by constant shot velocity.

EXPERIMENTAL

Flat samples of 16 MnCr 5, having a chemistry of C: 0,17, Si: 0,23, Mn:1,14, P: 0,011, S: 0,015, Cr: 0,92, Al: 0,04 in per cents, have been carbonitrided with 5 per cents ammonia at 900 °C. After the heat treatment the samples have been shot peened at a constant velocity of 50 m/sec for different lengths of time from 1 to 5 min. Rounded off wire shots of 0,9 mm dia. have been used for this treatment. Besides hardness measurements and metallographic investigations, mostly the changes in properties have been determined by X-ray diffraction methods.

RESULTS

Intensity, Microstructure and Hardness

The intensity of shot peening has been determined by means of measurement of deflexion on 1,3 mm thick Almen test plate (Horowitz, 1978). The curve in Fig. 1 shows changes in intensity as a function of shot peening duration.

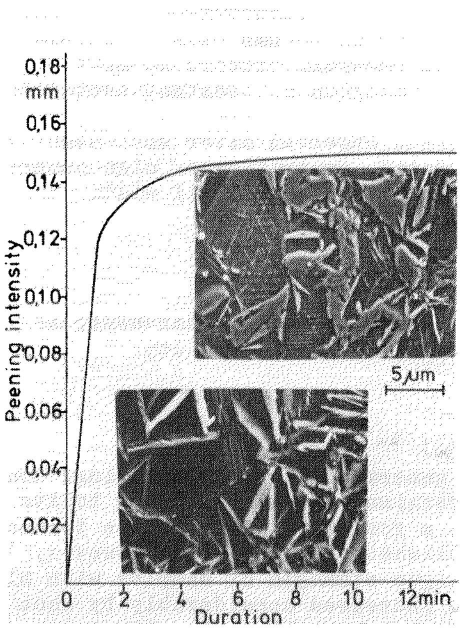

Fig. 1. Effective intensity and microstructure as a function of shot peening duration

Analogous to changes in intensity the microstructure of the carbonitrided case also changes with increasing shot peening duration. From the corresponding micrograph in Fig. 1 it can be seen, that before the commencement of shot peening, the structure of the carbonitrided case consists of martensite and retained austenite in almost equal shares. With increasing duration of shot peening, the bright patches of retained austenite take on colour increasingly and become darker. The growing etchability indicates γ to α transformation and/or precipitation. Transformation and precipitation processes can be initiated by plastic deformation (Wittkamp, Hornbogen, 1977). The slip lines in austenite, visible on the micrograph in the middle of Fig. 1, indicate plastic deformation in austenite.

The surface hardness as a function of shot peening duration has been shown in Fig. 2. To cover the hardness in different depths, the proof load has been varied between 2 and 60 kg. While the hardness in deeper layers remain, after initial increase, almost unaltered (HV 30, HV 60), the hardness in layers near to the surface increases continuously with shot peening duration, as shown by HV 2- and HV 10-hardness curves. The respective depths of penetration of Vickers pyramid by corresponding proof loads are indicated on each hardness curve.

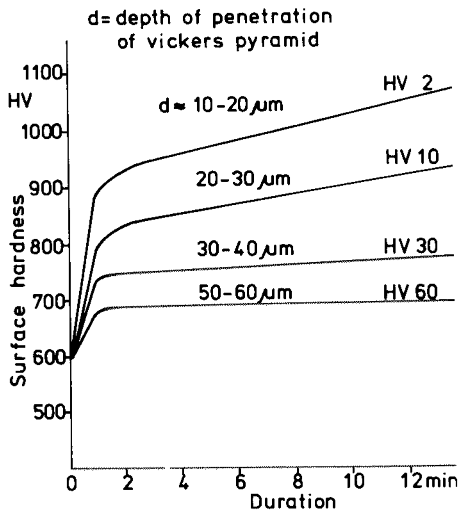

Fig. 2. Surface hardness as a function of shot peening duration; proof load as parameter

Retained Austenite, Residual Stresses and Surface Roughness

About 50 per cent of retained austenite has been determined by X-ray diffraction method on the surface of carbonitrided samples. As shown in Fig. 3 the amount of retained austenite decreases by half to about 25 per cent rapidly at first and than slowly with increasing duration of shot peening. Even after 15 minutes of shot peening, the surface structure still possesses about 15 per cent of retained austenite.

The residual stresses, measured on the surface according to $\sin^2\Psi$-method (Macherauch, Müller, 1961), change with shot peening duration, as shown in Fig. 3. Already after one minute of shot peening the initial compressive stresses increase substantially. There after the change in compressive stresses with increasing shot peening duration is little.

As shown in Fig. 3 the roughness of a not very finely ground surface diminishes to some extent in the beginning and then remains unaltered for the rest of shot peening duration. Sometimes it is reported, that shot peening also roughens a surface. Such discrepancies, however, do not pose any contradiction, if the different initial conditions of surfaces are taken into consideration. Obviously shot peening will not increase the smoothness of a very finely ground surface any further. On the contrary, a very smooth surface roughens, when exposed to shot peening treatment (Schreiber and others, 1978a, 1978c). Thus the final surface roughness will be dependent on initial surface condition as well as on different shot peening parameters.

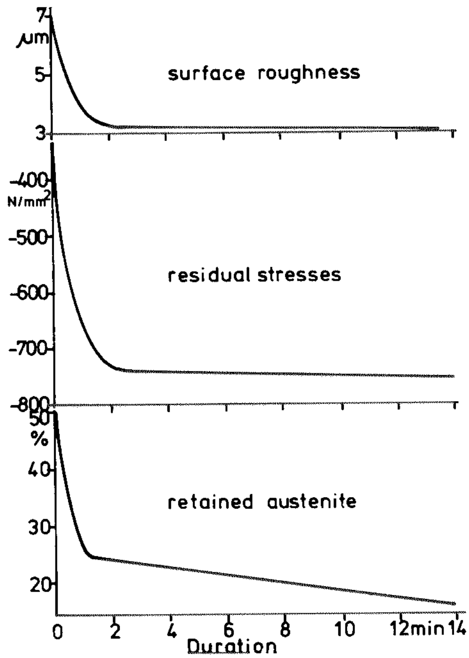

Fig. 3. Changes in surface roughness, residual stresses and retained austenite content as a function of shot peening duration

Crystal Orientation

The ratio of intensities of γ reflexes changes with increasing shot peening duration (Fig. 4). The intensity of γ (220) reflex drops first then increases with the duration, while the intensity of γ (311) reflex diminishes further. That means, that fcc austenite crystals increasingly orientate themselves with their slip planes parallel to the surface; austenite shows texture. This phenomenon can be explained with crystal morphology. Chrystallites, whose slip planes show a vertical orientation to the surface, will be stronly deformed and tilted during shot peening, while those with their slip planes parallel to the surface will be less affected. Thus it is likely, that with increasing duration of shot peening all slip planes gradually become parallel to the surface and the stable state condition sets in.

Such orientation effect in α crystals is less. The statistically irregular distribution of α crystals is mostly maintained, even after long duration of shot peening, as can be seen from the ratio of intensities of α (211) and α (200) reflexes in Fig. 4.

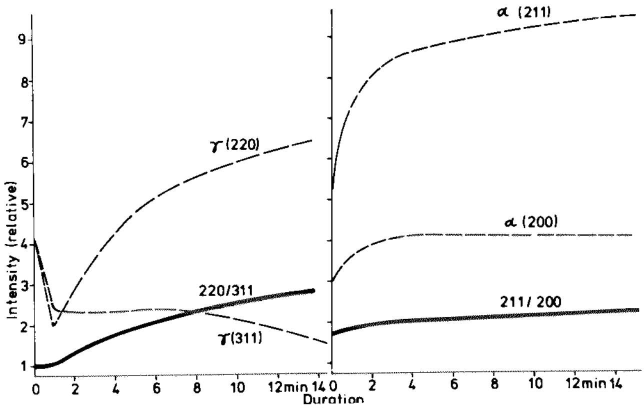

Fig. 4. Relative intensity of γ and α reflexes as a function of shot peening duration

Lattice Constant and Half Width

The lattice constant of retained austenite is independent of shot peening duration, while that of martensite increases in the beginning and then remains constant (Fig. 5).

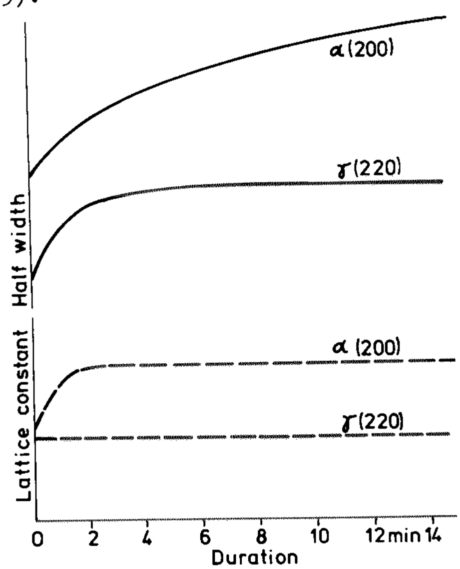

Fig. 5. Lattice constant and half width of α and γ phase as a function of shot peening duration

The half width of martensite increases with increasing shot peening duration, while that of retained austenite increases in the beginning and then remains more or less constant, as shwon in Fig. 5.

Cryogenic Treatment

Finally, as check test, carbonitrided samples have been exposed to shot peening after transforming most of retained austenite by cryogenic treatment at -196 °C. Changes in different properties of such samples are shown in Fig. 6, as a function of shot peening duration. After cryogenic treatment the share of retained austenite in the structure falls considerably. About 10 per cent of retained austenite remains almost constant during the entire period of shot peening. The roughness of the surface diminishes in the beginning and then remains constant. The lattice constant and the half width increase after cryogenic treatment. But during shot peening both of them fall in the beginning and then remain more or less constant. Substantial increase in the surface hardness has been observed after cryogenic treatment. With increasing duration of shot peening the surface hardness increases further.

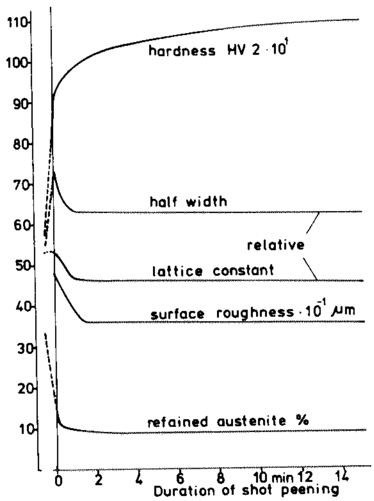

Fig. 6. Changes in properties of cryogenic treated samples as a function of shot peening duration

DISCUSSION AND CONCLUSIONS

The case of carbonitrided sample with high content of retained austenite will be hardend after shot peening treatment (Fig. 2). This, however, is a self inhibiting process. The increasing hardness of the surface works progressively as a protective shield for deeper lying layers. Thus the depth of hardening can be influenced only by variing shot impact energy and not by shot peening duration.

The increase in hardness is primarily due to transformation of retained austenite (Fig. 3) and work hardening of α phase (Fig. 5). The increase in half width of γ (220) in the beginning of shot peening indicates, that also austenite work hardens to some extent (Fig. 5). However, metastable retained austenite can be deformed and hardened only up to a certain extent. As soon as this limit is crossed the γ to α transformation is actuated. As can be seen in Fig. 3, the half of austenite crystals have already crossed the threshold of deformation after a short duration of shot peening and have been transformed. The remaining austenite crystals lie close to this threshold and cannot be deformed any further without transformation. With increasing surface hardness, however, the deformation becomes more difficult; hence γ to α transformation slows down (Fig. 3).

Contrary to (Schreiber, 1974) it has been established, that the half width of α reflex increases continuously with the duration of shot peening (Fig. 5), while that of γ reflex increases in the beginning and then remains constant, although austenite is more easily deformable than martensite.

The carbonitrided samples however, show, after cryogenic and shot peening treatment, some discrepancies (Fig. 6). Both the half width and the lattice constant of cryogenic treated samples decrease with increasing shot peening duration. In spite of that the surface hardness increases with the duration of shot peening.

The hardening behaviour of cryogenic treated samples after shot peening can not be explained either with γ to α transformation or with lattice distortion of α phase. A more likely explanation for the decreasing half width and lattice constant would be precipitations. These precipitations possibly play with dislocations a decisive role in the mechanism of hardening due to shot peening of cryogenic treated carbonitrided samples.

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