INFLUENCE OF SHOT VELOCITY AND SHOT SIZE ON ALMEN INTENSITY AND RESIDUAL STRESS DEPTH DISTRIBUTONS

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ABSTRACT
More than 150 batches of shot peened specimens made of annealed or quenched and tempered steel 42CrMo4 were prepared and investigated. Shot sizes S110, S170 and S230 were used in combination with different mass flows, nozzle diameters and nozzle distances. A specific system for the direct measurement of the velocity distributions of the shots was employed and results were correlated with the Almen intensities measured (Zinn, Schulz, Kopp, et al., 2002). In this paper, for characteristic examples the residual stress depth distributions produced and the full width at half maximum (FWHM) values of X-ray interference lines are discussed in dependency of Almen intensities and shot velocities. Maximum amounts of compressive residual stresses below the surface are only influenced by the materials state. All other peening parameters mainly influence the thickness of the layer with compressive residual stresses. In this context, shot diameter and shot velocity are most important.

SUBJECT INDEX
Shot velocity, Almen intensity, residual stress depth distribution

INTRODUCTION
The aim of the investigation was to identify the influence of different shot velocities, together with different shot sizes, nozzle diameters and nozzle distances on the resulting Almen intensities and surface layer properties. In a previous paper (Zinn, Schulz, Kopp, et al., 2002), first results for the shot size S110 were presented. Now, using shot sizes S170 and S230, a more detailed survey of the interactions of process parameters on the resulting near surface materials properties, especially the residual stress depth distributions, becomes possible.

METHODS
Rectangular specimens were prepared out of a flat plate with a thickness of 10 mm and an edge length of 50 mm. In addition to annealed (930 °C, 3 h, furnace cooling) specimens also quenched and tempered ones (850 °C, 20 min, oil, 300 °C, 2 hours, furnace cooling, 500 – 520 HV) were produced. Then specimens were shot peened using a conventional NC-controlled air pressure peening machine. The following peening parameters were applied:

shot diameter:	S110, S170 and S230
nozzle diameter:	10 mm and 15 mm
nozzle distance:	100 mm and 150 mm
mass flow:	S110: 200, 600 g/min. S170 and S230: 2000, 4000 g/min.
mean shot velocity:	S110: (20), 25, 30, 35, 40, 45 m/sec; S170: 25, 30, 35, 40, (45) m/sec; S230: 5, 10, 15 m/sec.

Residual stress measurements were carried out with a stationary X-ray diffractometer using Crkα-radiation diffracted at the {211} lattice planes of the material. For stress calculation, the constants E=210000 MPa and ν=0.285 were used.

RESULTS

Figure 1 shows residual stress depth distributions for specimens, peened with S110, a mass flow of 600 g/min, a nozzle diameter of 15 mm and a distance between nozzle and specimens of 100 mm. There is almost no influence of the peening condition on the maximum amounts of residual stresses, which are between –500 and –600 MPa for the annealed state and between –800 and –900 MP for the quenched and tempered state. However, it can clearly be seen, that increased mean values of the shot velocity, for both materials states, lead to thicker layers with compressive residual stresses. As expected, in the annealed state, increased FWHM-values near the surface are observed due to local inhomogeneous plastic deformation. In contrast to that, a pronounced FWHW-minimum occurs in the case of the quenched and tempered materials state, which can be attributed to peening induced microstructural alterations. FWHW-values immediately at the surface are smaller than in regions not affected by the shot peening process.

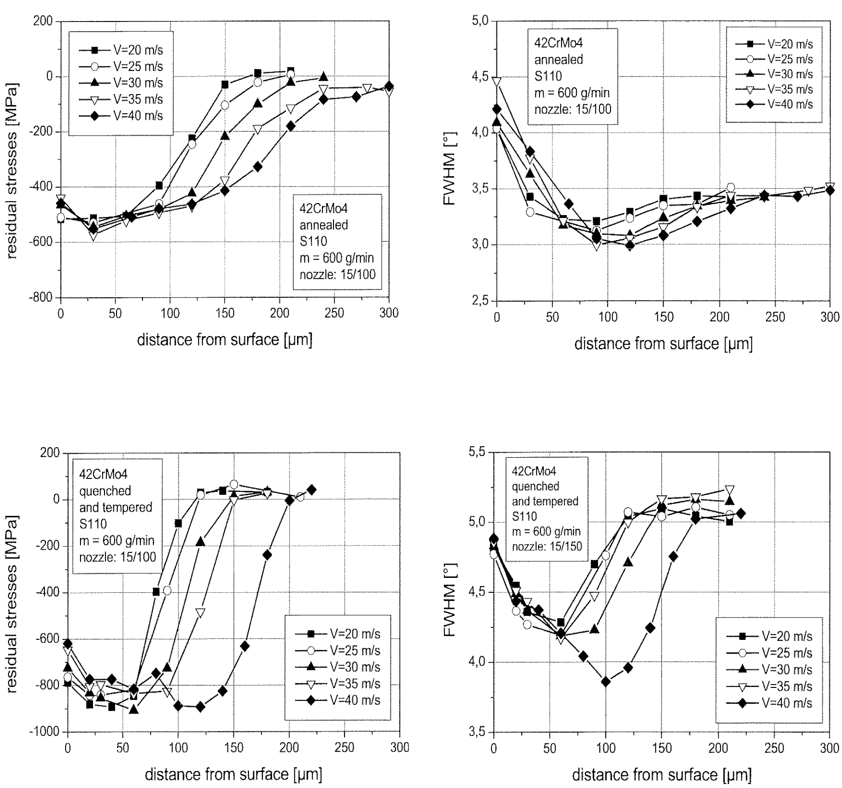

Figure 1: Residual stress (left) and FWHM (right) depth distributions of specimens shot peened with S110; annealed (above) and quenched and tempered (below)

Figure 2 shows results of specimens, peened with S170, a mass flow of 2000 g/min, a nozzle diameter of 10 mm and a nozzle distance of 100 mm. In principle, the results are comparable with the observations presented in Figure 1 and a similar influence of the mean values of the shot velocity can be found.

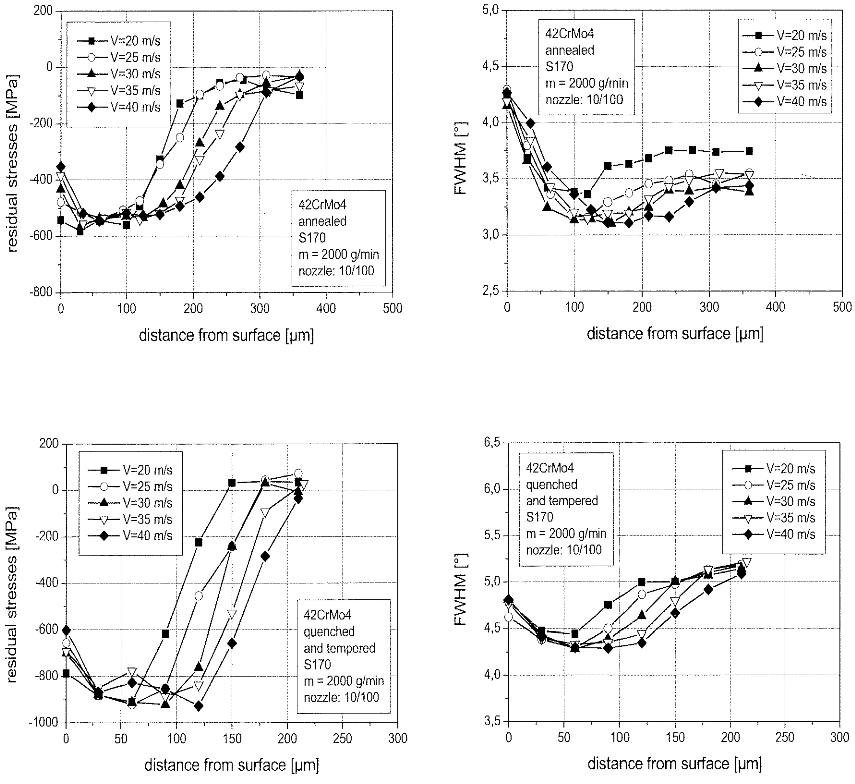

Figure 2: Residual stress (left) and FWHM (right) depth distributions of specimens shot peened with S170; annealed (above) and quenched and tempered (below)

Examples of depth distributions measured for specimens peened with S230 (mass flow: 2000 g/min; nozzle diameter: 10 mm; nozzle distance: 100 mm) are presented in Figure 3. In this case, only maximum mean values of shot velocity of 15 m/sec were possible. Also in this case, maximum residual stress amounts are comparable with the results presented in Figure 1.

DISCUSSION

In Figure 4, the relationships between Almen intensity and the mean values of the shot velocity are plotted for all process parameters investigated. It can clearly be seen, that Almen intensity values increase with increasing values of the mean shot velocity. For each shot size, the relationship can be represented by a straight line, however with considerably more scatter of the data with decreasing shot size. If S110 is used, the difference between the lowest and the highest Almen value for a given shot velocity is approximately 0.1 mm. For this shot size lowest Almen intensities are observed for a smaller nozzle diameter of 10 mm and a mass flow of 600 g/min.

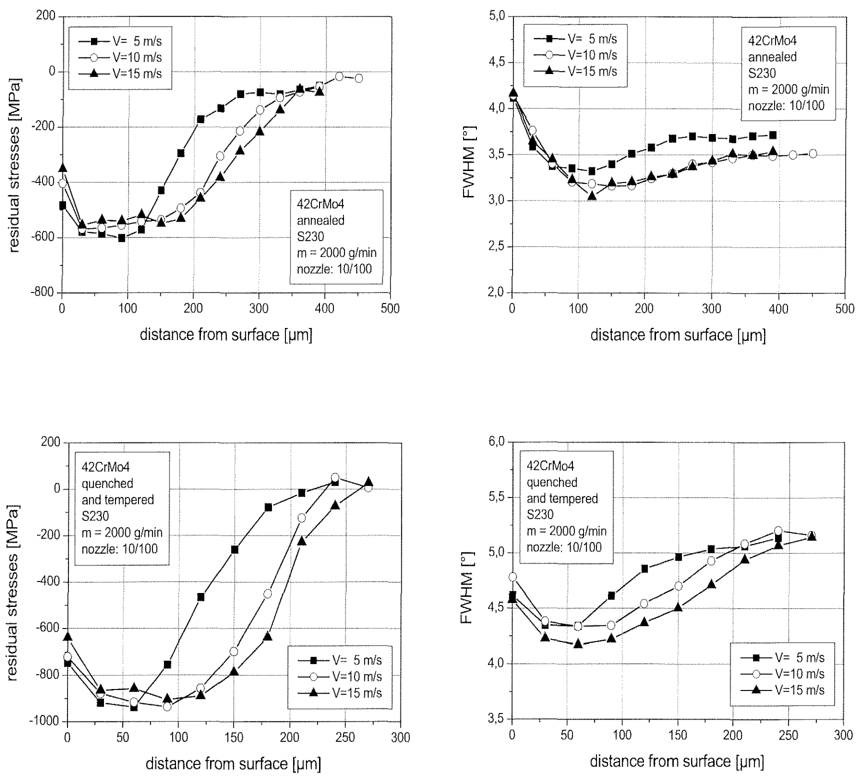

Figure 3: Residual stress (left) and FWHM (right) depth distributions of specimens shot peened with S230; annealed (above) and quenched and tempered (below)

A special point of residual stress depth distributions is the depth, where a residual stress value of zero is reached (depth of zero-crossing). If these values are plotted as a function of the Almen intensities used, distributions as shown in Figure 5 are observed. Whereas for the quenched and tempered materials state, all measured values nearly follow a straight line with a relatively small scatter band. For the annealed state, clearly different relationships are found for the individual shot sizes used during the peening process. Highest values (thickest layers with compressive residual stresses) are observed for the largest shot diameter S230. Other shot peening process parameters seem to be of minor importance.

From a practical point of view, the relationship between the on-line measurable shot velocity and the resulting residual stress depth distribution in the sample is of general interest. In Figures 6 and 7, the measured relationships are given for the annealed and the quenched and tempered states resp. Also in this case, the relationships can be described by straight lines for each shot size for the shot velocity ranges investigated. However, if the results are compared with the relationships shown in Figure 4, one can state, that obviously a larger scatter of the data exists for the influence of shot velocity on the depth of zero crossing of residual stress distributions than for the influence on Almen intensity. Moreover, the deviations cannot be attributed in a simple way to individual process parameters. This reflects the fact, that Almen intensities are not unambiguously correlated with shot peening induced residual stress distributions. The slope of the linear relationships decreases with decreasing shot size. Obviously, the influence of shot velocity on the thickness of the surface layer with compressive residual

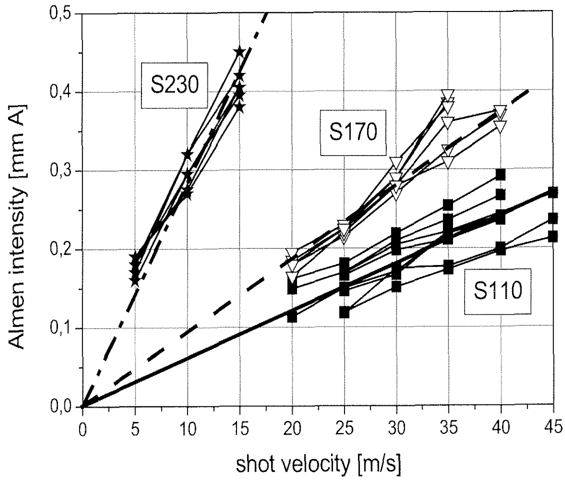

Figure 4: Almen intensity vs. shot velocity for different shot sizes

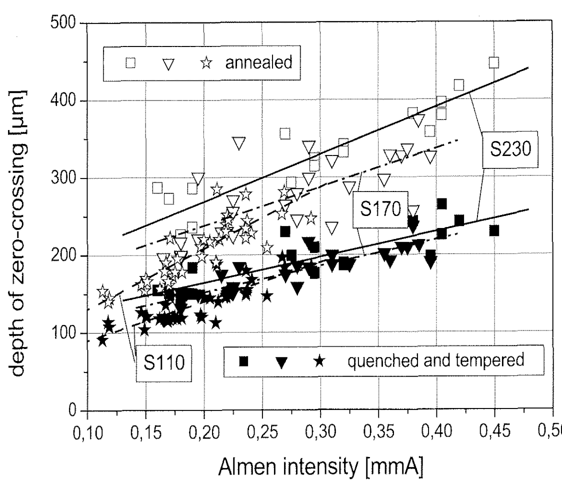

Figure 5: Depth of zero-crossing vs. Almen intensity for different shot sizes and materials states

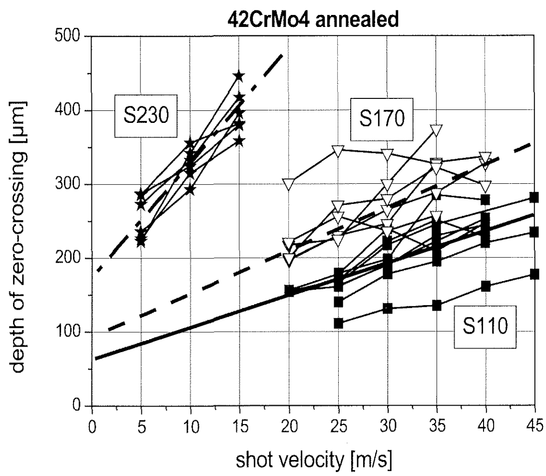

Figure 6: Depth of zero-crossing vs. mean shot velocity (annealed materials state)

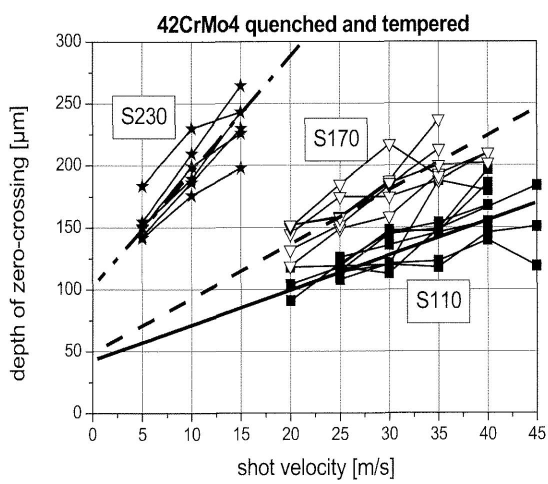

Figure 6: Depth of zero-crossing vs. mean shot velocity (quenched and tempered materials state)

stresses is the more important, the larger the shot size is. This has to be taken into account, if mean values of shot velocities are used as process control parameters in order to produce residual stress depth distributions requested. Thus the measurements presented clearly indicate the practicability and limits of quality control processes, if on-line measured mean values of shot velocities are used.

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