INFLUENCE OF SHOT PEENING MEDIA AND PARAMETERS ON CARBURIZED STEEL

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Abstract

The aim of this study is to determine the shot peening media and parameters which can introduce the strongest residual stress profiles while keeping a limited surface roughness on carburized steels. Another objective is to evaluate the ceramic shots Zirshot HDC and compare them to traditional metallic media. The influence of initial roughness and hardness of samples before shot peening was also investigated.

Keywords: *shot peening, ceramic shot, DOE, roughness, residual stress*

Introduction

In industry, shot peening is widely used to improve the fatigue properties through the introduction of compressive residual stress on a superficial layer [1]. Most studies are focused on only two of the parameters of this process, Almen intensity and coverage, but few studies show the effect of different types of media. Moreover, carburized steels are often difficult to shot peen due to their high hardness, and it is known that the media selection is of great importance [2], whereas the shot peening process can bring significant performance improvement [3]. There is hence a need for multi-parameter investigation of the shot peening process for this type of material. This development was carried out during TRANSFUGE project.

Experimental methods

Four kinds of specimens of 16MnCr5 steel were studied. Specimens were carburized, and then annealed at two different temperatures to obtain two different surface hardness (700HV and 800HV). Two different surface finishing were investigated, one whose surface roughness (R_a) is 0,3 µm and another with 1,6 µm of R_a. The geometry chosen is the same as an Almen A strip but 10 mm thick.

For studying simultaneously, the influence of shot peening parameters and the previously mentioned material parameters (surface hardness and initial roughness) a wide Design of Experiment (DOE) has been set up. The 3 process parameters that are studied are: media, Almen intensity and incidence angle. First a complete fractional DOE was stablished and then optimized using the software Minitab to reduce the number of configurations to study from 96 to 36. The table 1 shows the different parameters which were studied and their values.

Residual stress profiles were measured by X-ray diffraction using Cr-Kα radiation. Surface roughness was characterized by two methods: standard 2D measurements using the Mitutoyo SJ-210 roughness meter and 3D surface analysis using a GT contour microscope from Bruker. Statistical analyses of the results were carried out using Minitab software.

Table 1 : Process and material parameters

Parameter	Value
Almen Intensity	low; high
Media	CW400, CW600, ASH170, ASH230, ZC400, ZC600
Incidence angle	85°;45°
Coverage	200%
Projection	Nozzle – 10mm diameter
Initial roughness (Ra)	0,3µm ;1,6 µm
Surface hardness	700HV; 800HV

Experimental results and discussion
Influence of Shot Peening on Roughness

All parameters with a normalized effect greater than a certain value are considered to have a significant impact on roughness. This corresponds to the P value of the experiment plan using an alpha coefficient of 5%. The Pareto charts in Figure 1 show the normalized effect of each parameter and their combinations for R_a, R_z, S_a and S_z. Statistical analysis showed that all shot peening parameter have a direct effect on final roughness R_a, except for the incidence angle. The four most influential parameters are initial roughness, Almen Intensity, media, and surface hardness, in that order.

On the other hand, statistical analysis on other surface parameters R_z, R_p, R_v, S_a, S_z and S_m(0,8µm) showed that after initial roughness, media has the greatest influence, and not almen intensity.

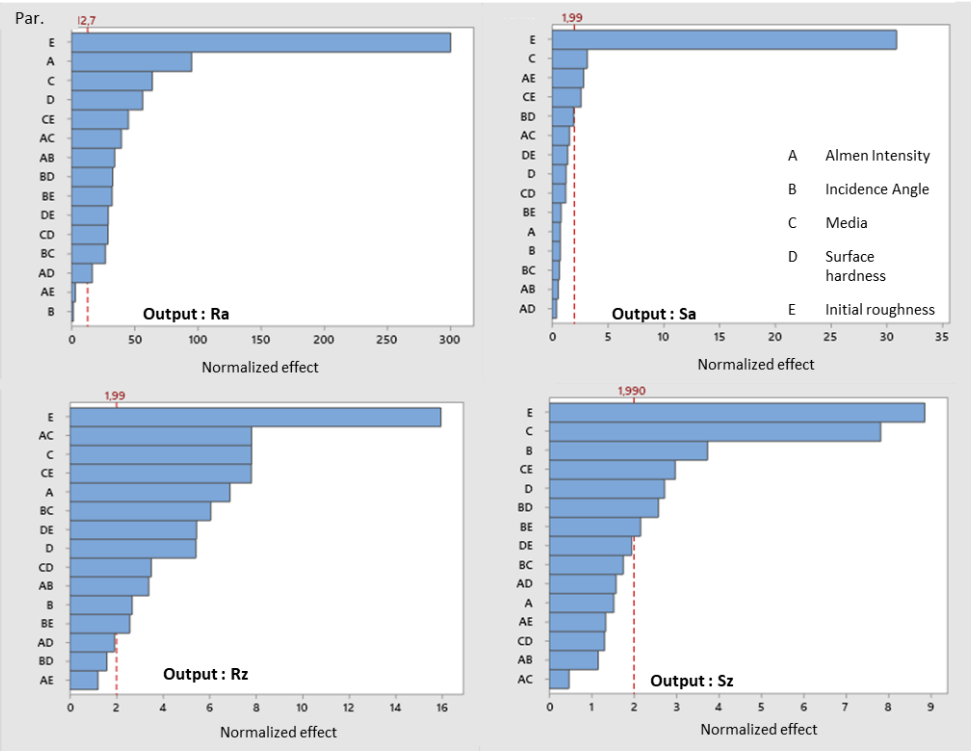

Figure 1 : Pareto chart for normalized effects on average roughness Ra, Rz, Sa and Sz for α=0.05.

Figure 2 shows the combined effect of parameters. This diagram reveals that initial roughness defines two different populations, and therefore has a strong interaction with other parameters. Final roughness is usually close to the initial one.

In this diagram the interaction between Almen intensity and media, the most influential parameters, is made explicit. The greater slope of the ceramic shots implies that these medias are more sensitive to Almen intensity than metallic ones for this kind of applications.

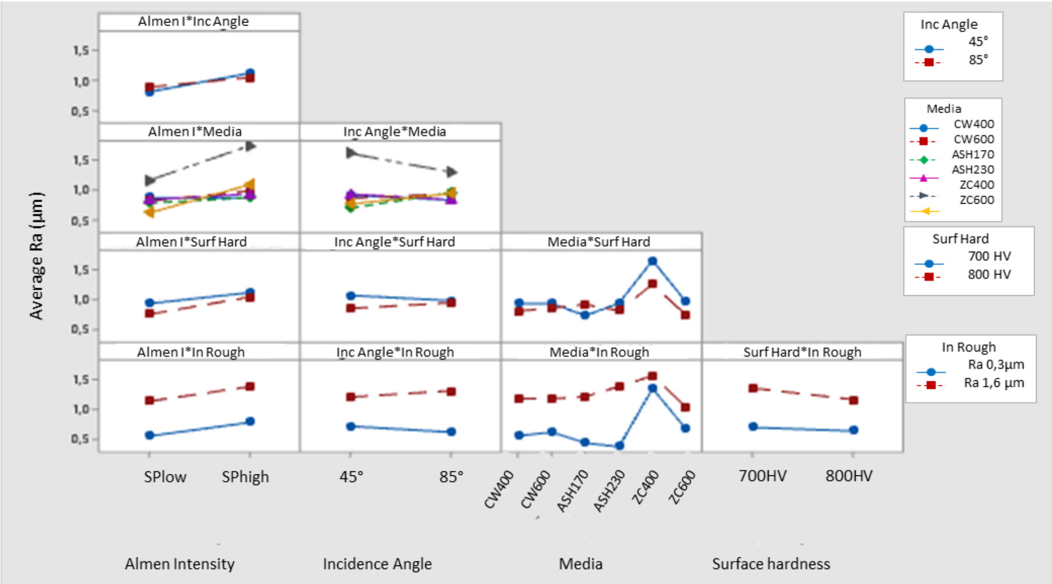

Figure 2 : Interaction diagram for Roughness parameter Ra (Adjusted averages)

Influence of Shot Peening on residual stress

To be able to analyze statically the effect of process and material parameters on residual stress, each one of the 36 residual stress profiles were characterized by 4 parameters: surface residual stress, maximum residual stress, peak position and affected depth. The Pareto charts in Figure 3 show the normalized effect of each DOE parameter and their combinations on Maximum Residual Stress. This diagram show that Media is the only parameter that has an influence. Statical analysis showed the same result for the surface residual stress and peak position, however affected depth is only determined by Almen intensity.

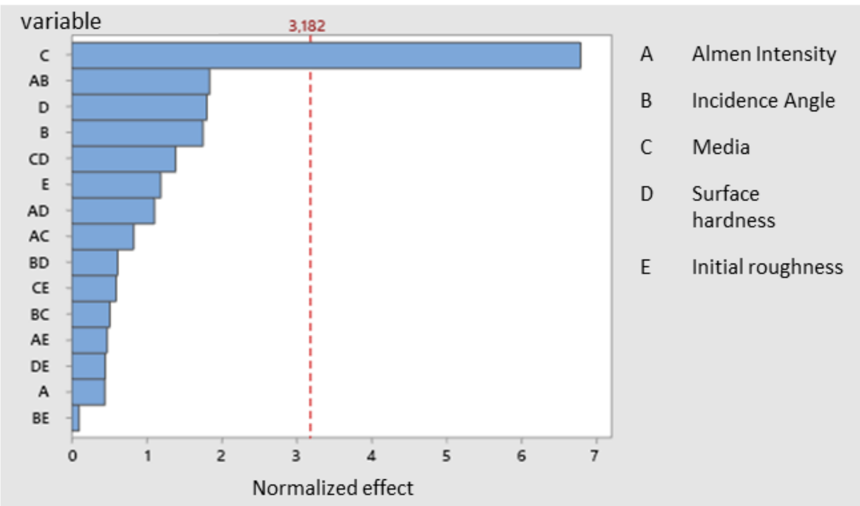

Figure 3 : Pareto chart for normalized effects calculated for maximal residual stress. α=0.05.

The interaction diagram for maximum residual stress in Figure 4 show clearly that each media produces a specific Maximum residual stress, independently of the Almen intensity or the incidence angle

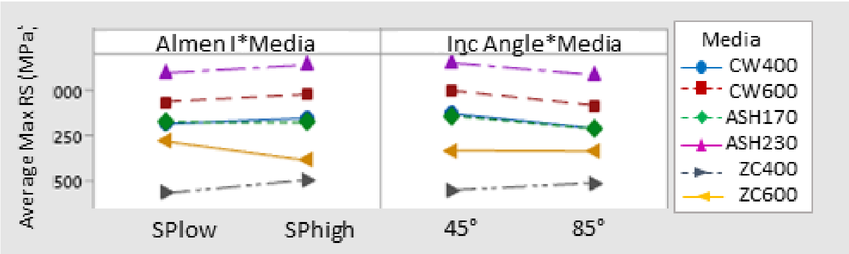

Figure 4 : Interaction diagram for Maximal Residual Stress (Adjusted averages)

Optimization

Different studies [4-8] associate a stress concentration factor K_t with the roughness parameter R_z. Therefore, certain shot peening conditions neutralize the beneficial effects of the residual compressive stresses by creating surface defects which increase the stress concentration factor. Consequently, it is not enough to evaluate the influence of shot peening on roughness and residual stress independently to choose the most suitable parameters. For this, diagrams which display simultaneously the influence on both for each configuration must be used.

Figure 5 shows maximum stress and R_z for each studied condition. Theses graphics show a distribution which is highly dependent on media for grinded samples (initial Ra 0,3µm), while in case of rougher samples there is not a clear distribution.
For grinded samples, media is a key parameter, being ceramic shots the ones that can introduce the strongest residual stresses but also strongly damage the surface. This suggests that ceramic shots should not be used at iso parameters regarding metallic media. Lower Almen intensity must be used for ZC shots to achieve suitable RS profiles and lower surface roughness.

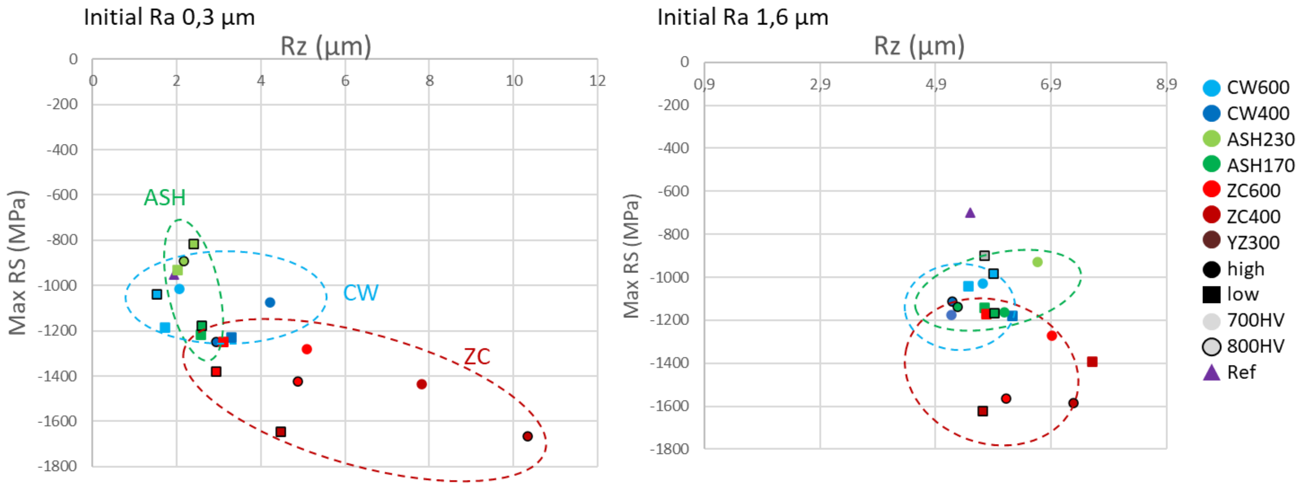

Figure 5 : Maximum residual stress and Rz after shot peening for each tested configuration

Conclusion

Analyses showed that media selection is a key parameter to consider for optimizing the ratio between the roughness generated by the shot peening and the intensity of the residual stresses. In particular, the ratio of hardness of the media to the target controls different behaviors: increasing this ratio allows to increase the residual stresses at the surface, while increasing the roughness sensitivity to the process parameters. The complete analysis allows to determine the influence of each factor tested. ZC shots should not be used at iso parameters regarding metallic media. Lower Almen intensity must be used for ZC shots to achieve suitable RS profiles and lower surface roughness

Acknowledgements

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