Surface properties and corrosion behaviour of shot peened AZ31 Mg alloy

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Abstract

This paper reports on the effects of shot peening on the surface layer properties and corrosion behaviour of AZ31 Mg alloy. Shot peening was carried out using two sizes of ceramic balls; Z850 (Φ 850 μm) and Z150 (Φ 125 – 250 μm). The Almen intensity was varied from 0.042 mmN to 0.2 mmN. The results referred to significant surface contaminants by using fine balls at high Almen intensities. The amount of these contaminants was reduced by using coarser balls and lower Almen intensities. Applying SP with different Almen intensities led to significant differences in polarization resistance and surface layer properties; residual compressive stresses and surface roughness.

Keywords: SP, ceramic balls, surface layer properties.

Introduction

Magnesium is the lightest structural metal with high specific strength, excellent machinability and good castability [1-2]. These advantages make magnesium alloys very attractive for the automotive industry. One of the drawbacks of magnesium alloys however is that magnesium has a hexagonal close-packed crystal structure, which limits the number of available slip systems [3]. Thus, magnesium alloys are relatively brittle, and it is difficult to manufacture components with complex geometries (such as wheels) by forging, and therefore for many applications magnesium components are produced by casting [4]. Fatigue properties of magnesium alloys are poor when compared to Al alloys, as proven by Wagner and co-workers, who studied the fatigue properties of wrought magnesium alloys AZ80, AZ31, and Al alloys 2024 Al [5] and 6082 Al [6]. They reported that fatigue strengths of the magnesium alloys were much lower than those of their Al counterparts [7]. Shot peening is a mechanical surface treatment technique widely considered as simple and comparatively cheap method to enhance the fatigue properties of structural metallic materials made of steel [8], aluminium, titanium [9] and Mg–Al alloys such as AZ31, AZ80 [10,11]. It is a process of affecting a surface with shot round metallic, glass or ceramic particles with force sufficient to create plastic deformation. It is similar to sandblasting, except that it operates by the mechanism of plasticity rather than abrasion: each particle functions as a ball-peen hammer. In practice, this means that less material is removed by the process, and less dust created [12]. The improvement in fatigue life stems from a combination of work hardening of the surface and an increased dislocation density, and the introduction of a near-surface compressive residual stress. Compressive surface residual stresses help to improve the life of engineering components by retarding fatigue crack initiation and growth [13]. However, the beneficial effect of shot peening can only be achieved by carefully selecting the peening parameters to avoid the strong overpeening effect [10,11,14]. There are many studies on fatigue properties of shot peened magnesium alloy [5,7,15]. The aim of this study is to perform a surface analysis of shot peened AZ31 samples in order to evaluate the effect of ceramic shot media size and used Almen intensity.

Experimental Methods

Magnesium alloy AZ31 was used in this investigation. Its chemical composition is listed in Table 1. It was prepared by a continuous casting followed by a homogenous ageing at 420 °C for 16 hours. The tested material had an average grain size of 220 μm (Fig. 1) and the microstructure revealed polyhedral grains of solid solution of aluminium, zinc and other alloying elements in magnesium.

Table 1 Chemical composition of AZ31 alloy

Component	Al	Zn	Mn	Si	Cu	Ni	Fe	Mg
wt. %	2.96	0.828	0.433	0.004	0.004	0.001	0.002	balance

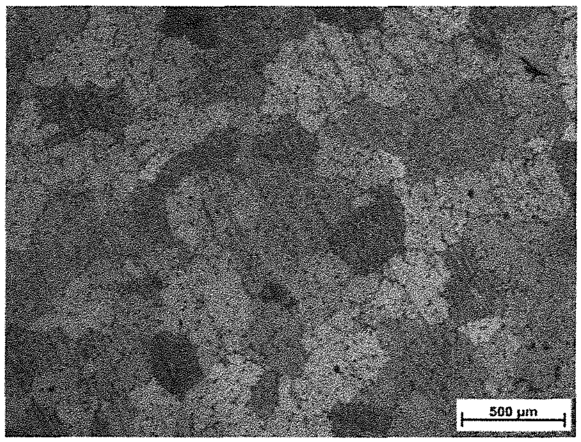


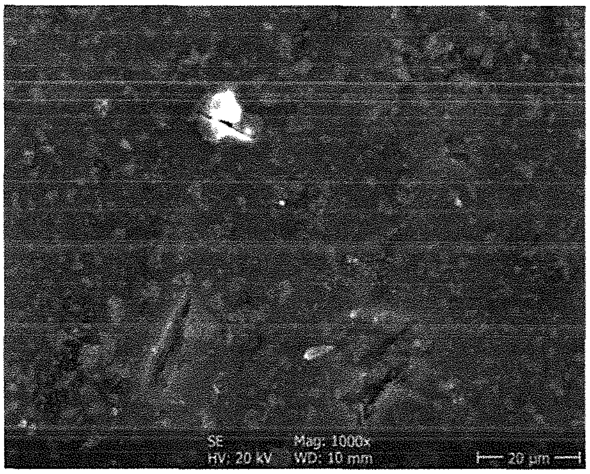
Fig. 1 Microstructure of AZ31 Magnesium alloy, light microscopy, etch. picric acid + ac. acid + ethanol + distilled water

The samples were treated by grinding (P1000 emery paper) and shot peening (SP). Shot peening was performed on a grinded surface using ceramic balls with different diameter Z850 (φ 850 μm) and Z150 (φ 125 – 250 μm). Almen intensities of 0.140 mmN and 0.042 mmN were used when shot peening by ceramic balls Z850 and Almen intensities of 0.200 mmN and 0.120 mmN were used when shot peening by ceramic balls Z150. Shot peening was followed by air streaming and ultrasonic cleaning in ethanol in order to remove impurities from shot peening process and rests of ceramic medium. The surface morphology observation and EDX analysis of shot peened surfaces was realized by scanning electron microscopy (SEM). Surface roughness was measured by perthometer PPK8 on a normalised distance 5.6 mm. Induced residual stresses after SP were measured by using incremental hole drilling method. Electrochemical properties were characterized through the measurements of the corrosion rate and polarization resistance.

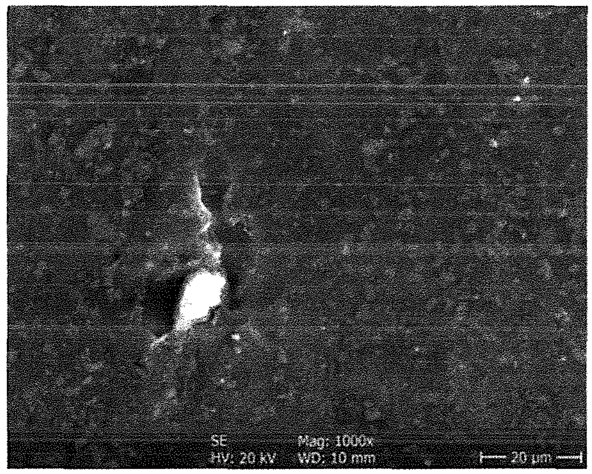
Experimental Results

SEM images of AZ31 surface shot peened by various Almen intensities and ceramic balls type are listed in Fig. 2. As can be seen, shot peening by ceramic balls causes surface contamination of soft magnesium alloy by damaged ceramic particles at all possible used Almen intensities. Fig. 2d shows, that the deformation of the surface after shot peening by Z850 ceramic balls with Almen intensity of 0.042 mmN is not such intensive, so that it could overcome the scratches caused by grinding prior to shot peening. EDX analysis of a contamined surface is listed in Fig. 3, which shows evidence of the presence of ceramic medium composed of Zr and Si on a shot peened surface although it was ultrasonically cleaned.

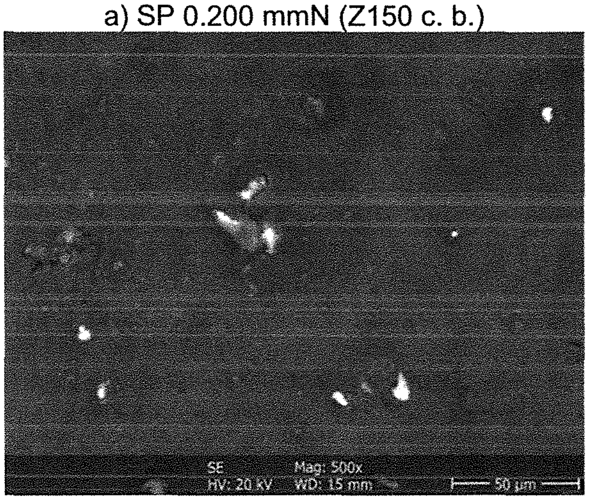
Shot peening significantly influenced the surface roughness also as can be seen in Table 2. Surface roughness measurements performed on AZ31 samples shot peened by ceramic balls (Φ 850 µm) were also studied in our previous study [16].
Further research was performed on samples shot peened by ceramic balls Z850 representing better surface quality. Fig. 4 shows the induced residual compressive stresses after SP at 0.042 mmN and 0.140 mmN. The effect of shot peening on the electrochemical characteristics is illustrated in Fig. 5.



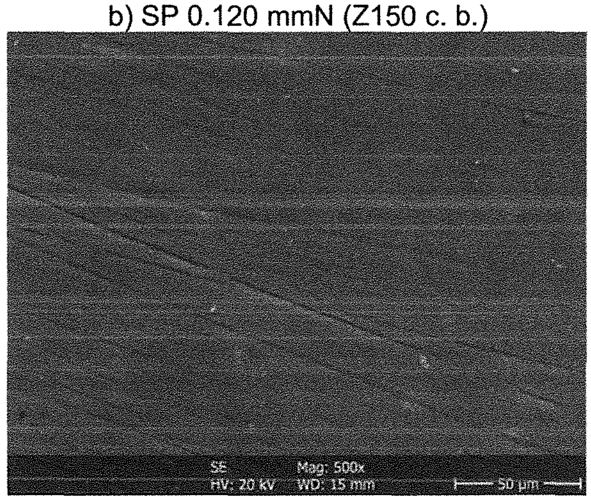
a) SP 0.200 mmN (Z150 c. b.)



b) SP 0.120 mmN (Z150 c. b.)



c) SP 0.140 mmN (Z850 c. b.)



d) SP 0.042 mmN (Z850 c. b.)

Fig. 2 Detail view of the surface shot peened by various Almen intensities (AZ31 alloy)

Table 2 Surface roughness parameters after various surface treatments

	R_{max} [µm]	R_z [µm]	R_a [µm]
Grinded surface (1000 grit paper)	2.98-3.72	2.93-2.75	0.34-0.32
SP 0,042 mmN (c.b. Φ850 µm)	9.08-10.17	7.76-8.46	1.42-1.75
SP 0,140 mmN (c.b. Φ850 µm)	9.85-13.75	7.83-10.25	1.56-1.89
SP 0,120 mmN (c.b. Φ125-250 µm)	7.31-9.61	6.46-7.40	1.14-1.37
SP 0,200 mmN (c.b. Φ125-250 µm)	11.28-14.38	9.61-11.57	1.72-2.03

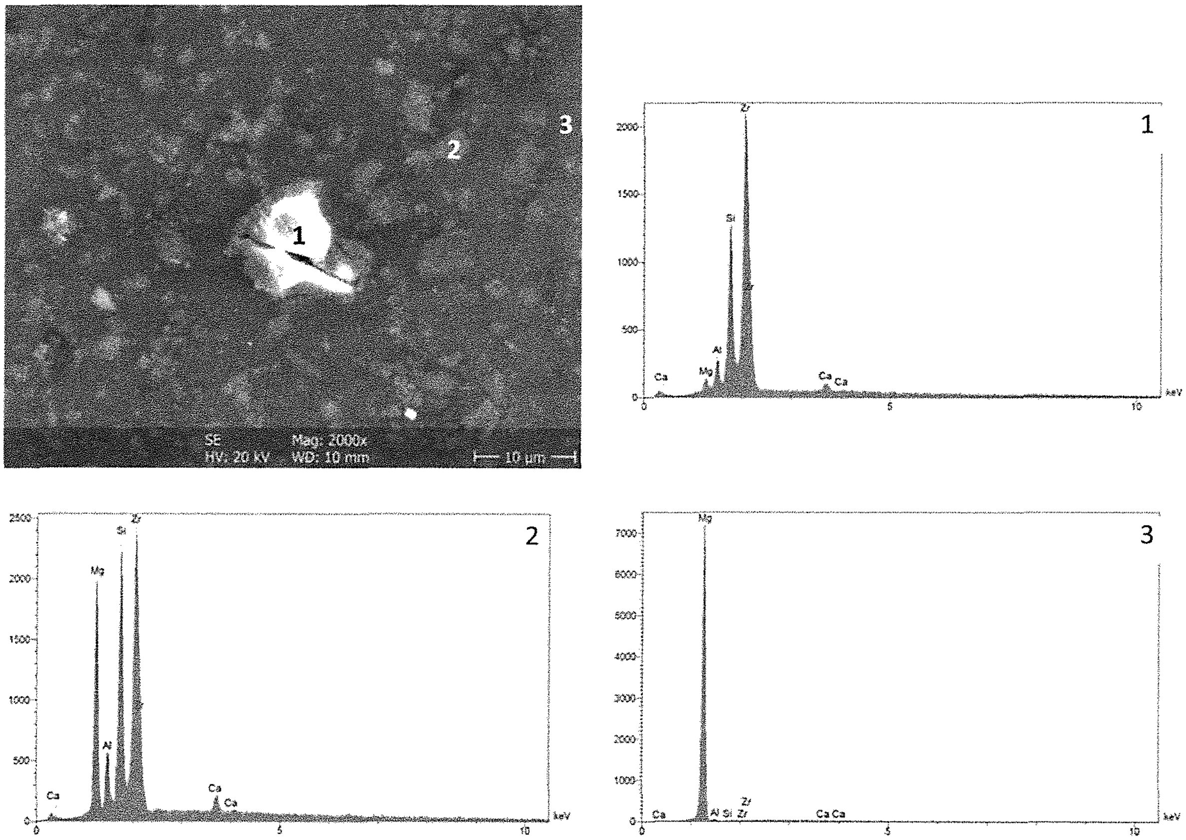
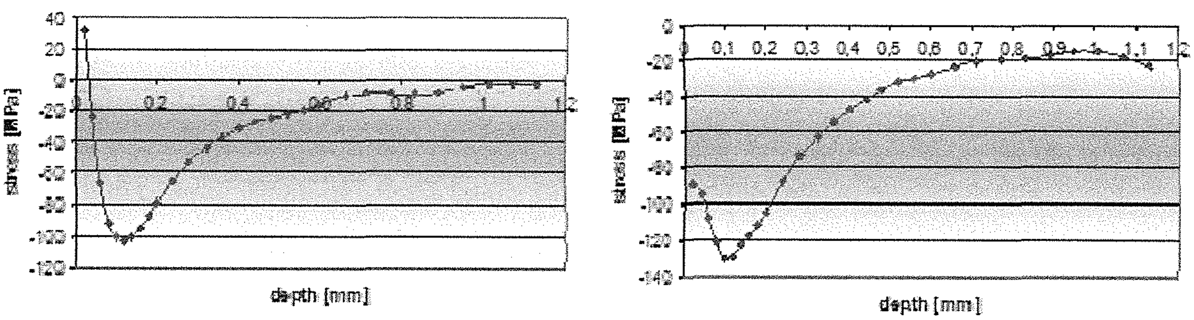
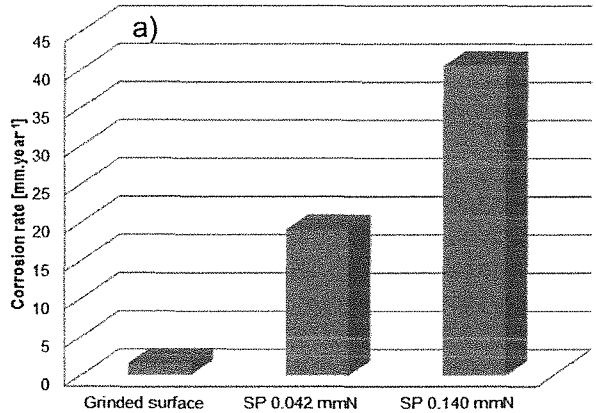


Fig. 3 EDX spectra of a surface (AZ31 alloy) shot peened by ceramic balls Z150 using Almen intensity of 0.120 mmN



a) SP 0.042 mmN *b) SP 0.140 mmN*

Fig. 4 Induced residual compressive stresses



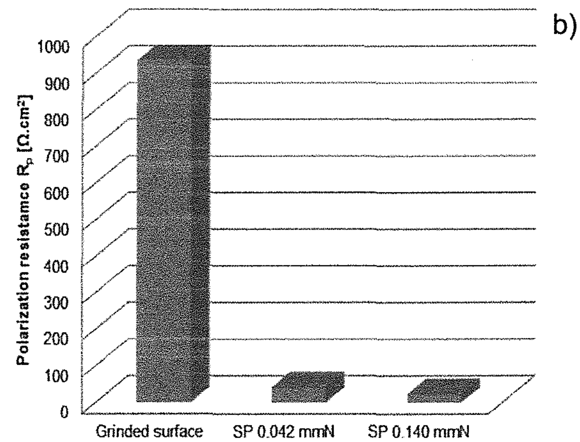


Fig. 5 Influence of various surface conditions on (a) corrosion rate, (b) polarization resistance

Discussion and Conclusions:

As can be seen from Fig. 2, surface morphology of AZ31 magnesium alloy is strongly influenced by used ceramic balls and by used Almen intensity also. There is a significantly higher number of ceramic medium particles stranded in the base material after shot peening by Z150 ceramic balls followed by cleaning process compared to surface shot peened by Z850 ceramic balls. In addition, a lot of notches caused by fractured ceramic shot medium parts can be found on a surface, which can possibly result in lowered fatigue properties of the samples. These findings show that ceramic balls with lower diameter (Φ 125-250 μm) are more detrimental for AZ31 magnesium alloy surface when they become damaged. These damaged particles are very small and sharp which allows them easily to infiltrate the base material.

Usage of lower Almen intensity is another alternative allowing reduction of stranded particles amount. There are almost no contaminants present on the surface shot peened by Z850 ceramic balls at 0.042 mmN. On the other hand, usage of such low Almen intensities results in not such intensive plastic deformation of the surface when there are still some scratches from grinding process present on shot peened surface.

Surface roughness of AZ31 samples after shot peening was higher at all conditions compared to grinded surface. The higher the Almen intensity was used, the higher the surface roughness.

As shown in Fig. 4, increasing the Almen intensity from 0.042 to 0.140 mmN resulted in a marked increase in the induced residual compressive stresses. SP-surfaces revealed lower corrosion resistance as illustrated in Fig. 5a and 5b. Compared to the as-grinded surface, SP samples exhibited higher values of corrosion rate and lower polarization resistance. Moreover, increasing the SP Almen intensity led to further decrease of the corrosion resistance.

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