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RESIDUAL STRESSES IN SHOT-PEENED SHEETS OF AlMg4.5Mn ALLOY

REZIDUALNE NAPETOSTI V PESKANIH PLOČEVINAH IZ ZLITINE AlMg4.5Mn

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An investigation of the residual stresses in shot-peened sheets of AlMg4.5Mn alloy involving surface-coverage measurements and the depth of the shot prints is presented.

The deflection method, based on models of residual-stress distribution connecting the depth, the moment loading and the elastic bending, is applied. The induction of residual stresses during shot peening is intensive. The elastic-plastic bending of sheet samples can be modeled by applying the equation of an elastic line of a bend cantilever. It requires the separation of the elastic and plastic bending components.

By removing layers from the shot-peened surface and by measuring the maximum bending, the position of the neutral surface can be defined: it amounts to 0.6-0.8 H_o. By assuming a linear stress distribution with the maximum at the surface, the relations for moment loading were determined and the residual stresses were calculated.

The achieved values of surface stress are close to the material's yield strength and depend significantly on the plastic deformation. The stress isotropy is connected with the shot-peening conditions and it is maintained up to ~90% of the surface coverage.

Key words: Al alloy, shot peening, coverage, residual stresses, distribution, deflection.

Opisana je raziskava rezidualnih napetosti v pločevini iz zlitine AlMg4.5Mn, pokritja površine in globine odtiskov. Uporabljena je metoda defleksije na osnovi modelov razdelitve napetosti z upoštevanjem globine, momenta obremenitve in elastičnega upogiba. Indukcija rezidualnih napetosti med peskanjem je intenzivna. Elastoplastični upogib vzorcev pločevine je mogoče modelirati z uporabo elastične linije upognjene plošče. Potrebna je ločitev elastičnega in plastičnega upogiba.

Z odstranitvijo plasti s peskane površine in merjenjem največjega upogiba je mogoče opredeliti nevtralno ploskev, ki je pri 0,6-0,8 H_o. S predpostavko o linearni porazdelitvi napetosti z maksimumom na površini so bile določene odvisnosti od momenta obremenitve in izračunane rezidualne napetosti.

Napetost na površini je blizu meje plastičnosti in je odvisna od plastične deformacije. Izotropija napetosti je povezana z razmerami pri peskanju in se ohranja do 90 % prekritja površine.

Ključne besede: zlitina Al, peskanje, prekritje, rezidualne napetosti, porazdelitev, upogib

1 INTRODUCTION

Shot peening is an effective way of strengthening and pre-stressing elements for cars, aircraft, ships, etc. The residual compression stress in the metal layers near the surface increases their lifetime[1-8], and as a result the surface state, the stress intensity and the affected depth can vary with respect to the applied shot-peening parameters - time of shot peening, surface coverage, and shot size [1,2,5,6]. The high level of the residual stresses is very significant for elements whose mechanical properties are often anisotropic as a result of the production process[2,3].

The possibility of determining the stresses using the deflection method depends on the sheet thickness, because this depends on the section modul. The residual stresses increase continuously during the shot peening until they exceed the yield strength and cause the elastic-plastic bending of thin sheets. By measuring the bending line and by separating the elastic and plastic deformations of the sheet samples it is possible to calculate the residual stresses. For this reason it is also necessary to know the distribution of the stresses in terms of depth [9].

The results of our investigation of residual stresses after shot peening sheets of AlMg4.5Mn alloy are presented in this paper, we have taken into account surface-coverage measurements as well as the depths of the shot prints.

2 EXPERIMENTAL

2.1 Material

The investigated material was an AlMg4.5Mn alloy with the chemical composition as shown in **Table 1**.

2.2 Sample preparation and investigation procedure

The sheet used in the experiments was 1.28-mm thick. It had a polished surface and its mechanical

Table 1: Chemical composition and mechanical properties of the investigated AlMg4.5Mn alloy
Tabela 1: Kemična sestava in mehanske lastnosti raziskane zlitine AlMg4.5Mn

	Chemical composition (%)								Mechanical properties		
	Mg	Mn	Si	Fe	Cu	Cr	Zn	Ti	$R_{p0.2}$ (Mpa)	R_m (Mpa)	A (%)
AA 5083	4.0-4.9	0.4-1.0	0.40	0.40	0.10	0.05-0.25	0.25	0.15	133	271	21.5
Investigated alloy	4.23	0.42	0.13	0.26	0.015	-	0.02	-	134.7	289.7	22.86

Table 2: Average surface coverage and bending values with respect to the shot-peening time of the square samples
Tabela 2: Povprečno prekritje površine in upogibne vrednosti pri kvadratnih vzorcih v odvisnosti od časa peskanja

Samples	S1	S2	S3	S4	S5	S6	S7	S8
Duration, (sec)	5			10			15	
Coverage, (%)	57.7	59.1	76.1	76.5	77.3	88.4	88.6	89.2
f_{max}, (mm)	3.23	3.91	6.55	8.14	8.51	11.25	12.11	12.74
f_{el}, (mm)	1.24	1.24	1.28	1.28	1.28	1.28	1.28	1.28
$f_{el.r}^{*} = f_{el} / f_{max}$	0.384	0.317	0.195	0.158	0.150	0.114	0.106	0.100

* relative ratio of the elastic component in the total bending

properties are shown in Table 1. Square samples of 80 × 80 mm and round samples of 64 mm diameter were cut from the sheet. The shot peening was performed with steel shot of 700 μm diameter for three different times (5, 10 and 15 sec) for the square samples and five different times (10, 15, 20, 30 and 40 sec) for the round samples. The square and round samples in their initial and shot-peened states are shown in **Figure 1**. The samples were fastened symmetrically with elastic strings to a steel base.

The surface coverage was estimated with an optical microscope by measuring the length of the dark-field prints on a 2-mm-long grid at 50× magnification. The diameters of individual prints were measured in the same way.

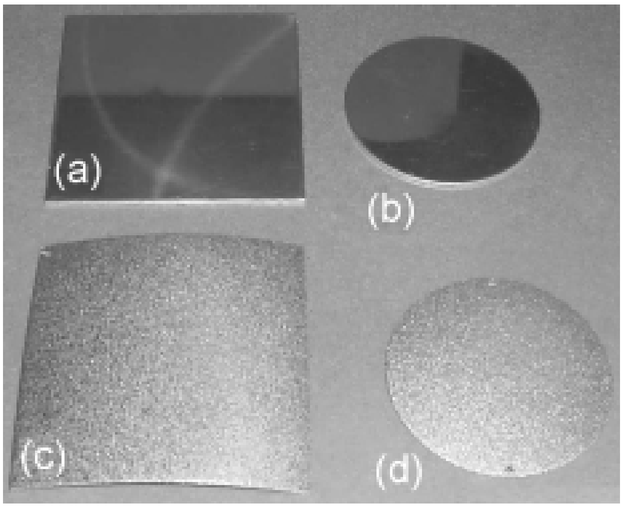

Figure 1: Square (a) and round (b) sheet samples before shot peening and their shape after shot peening with surface coverage ~60 % (c) and ~90 % (d)
Slika 1: Kvadratni (a) in okrogli (b) vzorci pločevine pred peskanjem in njihova oblika po njem s prekritjem površine ~60 % (c) in ~90 % (d)

Table 3: Average surface coverage and maximum bending values with respect to the shot-peening time of the round samples
Tabela 3: Povprečno prekritje površine in največje upogibne vrednosti v odvisnosti od časa peskanja za okrogle vzorce

Samples	Duration (sec)	Coverage (%)	f_{max} (mm)		Δf
			RD	TD	
R1	15	87.8	3.27	3.16	0.11
R2		89.0	3.84	3.19	0.65
R3		88.9	4.15	2.19	1.96
R4		88.6	2.81	3.14	0.33
R5	20	92.7	3.83	3.19	0.64
R6		91.7	6.72	2.33	4.39
R7		90.6	5.22	2.03	3.19
R8		91.0	1.70	7.08	5.38
R9	25	-	3.57	6.52	2.95
R10		95.9	3.86	5.59	1.73
R11		-	9.03	1.97	7.06
R12		95.3	6.02	4.56	1.46
R13	35	>100	1.88	8.72	6.84
R14			9.31	2.02	7.29
R15			11.23	1.24	9.99
R16			10.20	1.94	8.26
R17	45	>100	3.30	11.32	8.02
R18			5.62	9.52	3.90
R19			8.29	5.46	2.83
R20			1.69	12.93	11.24

For the determination of stresses using the deflection method one square sample for each of the coverage times was chosen. By etching with a 20 % NaOH solution at room temperature the metal from the shot-peened surface was uniformly removed. The remainder of the sample was protected by a solution-resistant covering. The average time for the removal of a layer approximately 100 μm thick was 120 minutes. The uniformity of the etching was controlled by measuring the thickness. We observed that the roughness of the surface was not significantly changed by the etching. The bending line was determined using an instrument with a scale of 0.01 mm.

Table 4: Experimental results for the dependence of the bending line and the stress values on the thickness of the removed layer for selected square samples
Tabela 4: Rezultati preizkusov za vsebnosti upogibne črte od napetosti po odvzemu površinske plasti za izbrane kvadratne vzorce

Samples	Thicknes of removed layer		f_{max} (mm)	Equation of bending line $y = a\cdot x^2$	MSE	f_{el} (mm)	$f_{el.r}$ (f_{el} / f_{max})	Transversal residual stress σ_p (MPa)
	Partial Δ_p, (μm)	Total Δ, (μm)						
	0	0	3.91	$y=3.221\cdot x^2$	0.239	1.24	0.317	-186.2
	108	108	3.67	$y=3.052\cdot x^2$	0.326	1.00	0.272	-119.1
S2	106	214	3.46	$y=2.892\cdot x^2$	0.188	0.79	0.228	-105.2
	96	310	3.18	$y=2.659\cdot x^2$	0.038	0.51	0.160	-78.4
	98	408	2.85	$y=2.382\cdot x^2$	0.216	0.18	0.063	-34.3
	0	0	6.55	$y=5.870\cdot x^2$	0.124	1.28	0.195	-160.4
	117	117	6.35	$y=5.715\cdot x^2$	0.068	1.08	0.170	-119.7
S3	113	230	5.97	$y=5.403\cdot x^2$	0.179	0.70	0.117	-83.4
	104	334	5.62	$y=5.086\cdot x^2$	0.088	0.35	0.062	-45.5
	105	439	5.19	$y=4.706\cdot x^2$	0.092	-	-	-
	0	0	12.11	$y=11.499\cdot x^2$	0.407	1.28	0.106	-157.7
	114	114	11.84	$y=11.295\cdot x^2$	0.485	1.01	0.085	-108.8
S7	106	220	11.44	$y=10.913\cdot x^2$	0.489	0.61	0.053	-66.7
	97	317	11.03	$y=10.557\cdot x^2$	0.152	0.20	0.018	-23.2
	99	416	10.49	$y=10.103\cdot x^2$	0.426	-	-	-

The degree of isotropy of the residual stresses was determined on the round samples by comparing the measurements in two mutually orthogonal directions: the rolling direction (RD) and the transverse direction (TD).

3 RESULTS

The average values for the coverage of the square samples with respect to the shot-peening time, as well as to the maximum bending value (f_{max}) and its elastic component (f_{el}) are shown in **Table 2**. The average values of coverage on the round samples with respect to the shot-peening time and the maximum bending values in the RD and TD are listed in **Table 3**. The maximum bending value and the elastic component of the residual stresses with respect to the thickness of the removed layer on selected square samples are shown in **Table 4**. This table also shows the equations for the bending line, deduced from the mean-square-error (MSE) approximation of the measured values and the second-order equation of the bending line.

4 ANALYSIS OF RESULTS

4.1 Surface coverage

The surface coverage with shot prints given in **Tables 2 and 3** represents the average experimental values. With respect to the shot-peening time, these values range from 57 % for 5 s. to 100 % after 35 s. The smallest surface coverage for an observation area of 2-mm diameter is approximately 20 prints. The number of observation fields for every measuring direction was approximately 40. The average values for three measuring directions are shown in **Tables 2 and 3**.

The surface coverage on different parts of the shot-peened surface varies over a wide range and differs significantly from the average value; this is clear from the data acquired from sample S1 in **Table 5** and the frequency statistic curve in **Figure 2**. The average value for the measured directions is 55-60 %, with the minimum value as low as 20 %, the maximum value equal to 80 % and the standard deviation equal to 2-16 %. The frequency curve in **Figure 2** shows the result for the whole sample with approximately 120 assessment

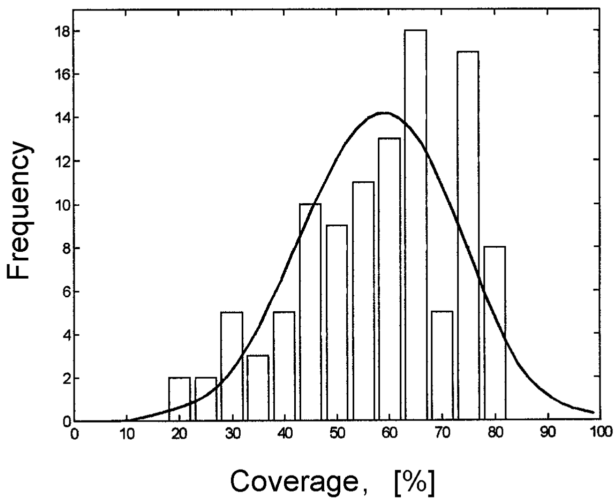

Figure 2: The coverage-distribution curve for the whole surface of sample S1
Slika 2: Porazdelitvena krivulja za prekritje cele površine vzorca S1

fields along the three directions: 1, 2 and 3. The frequency of the average values is approximately 14.

Table 5: The coverage index for the chosen assessment positions for square sample S1
Tabela 5: Indeks prekritja za izbrana merilna mesta za kvadratni vzorec S1

Measured direction on sample	Coverage index			Standard deviation
	Max	Mean	Min	
1	80	60.1	22	14.3
2	78	58.0	30	12.6
3	77	55.1	22	16.5
Complete sample	80	57.7	22	14.6

The surface appearance of the shot-peened sample depends not only on the coverage but also on the depth of the shot prints (h_p), which can be calculated from the diameter of the prints (D_p) (**Figure 3a**) using the relation:

$$h_p = r_b - \sqrt{r_b^2 - r_p^2}, \qquad (1)$$

where: $r_b = D_b/2$ - ball radius;
$r_p = D_p/2$ - print radius.

The calculated print depths were in the range from 34 to 170 μm, and the average depth of all the measured prints was of 78 μm. The print depth is, as shown in **Figure 3b**, proportional to the ball diameter in the range of print depths versus ball diameter from 0.049 to 0.243, with the average value being 0.111. Also significant is the ratio of print depths versus sheet thickness, which is in the range from 0.026 to 0.133.

(a)

(b)

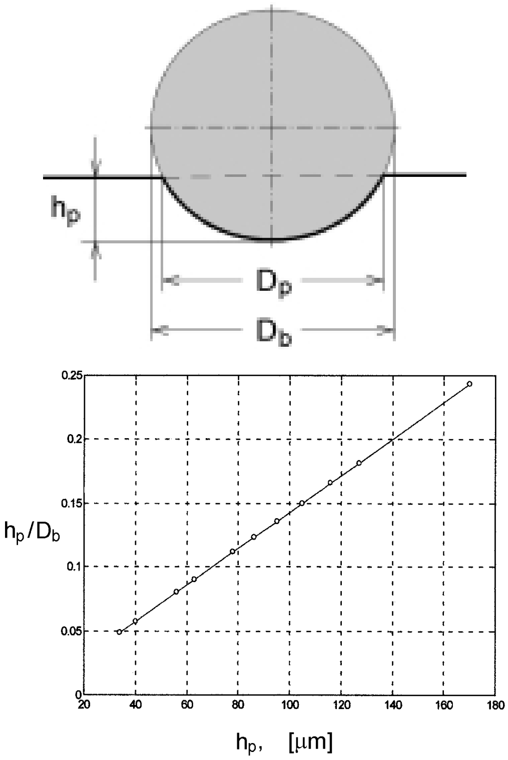

Figure 3: A ball print at the sheet surface (schematic) (a) and print-depth values (h_p) in relation to the ball diameter (D_b) (b)
Slika 3: Odtis kroglice na površini pločevine (shematično) (a) in globina odtisa (h_p) v odvisnosti od premera kroglice (D_b) (b)

4.2 Bending line

The shot-peening process produces residual compression stresses in sheet layers below the surface. These stresses increase continuously to values that exceed the yield stress and cause a plastic bending deformation of the sheet specimen. As a consequence, the bending has an elastic-plastic character (**Figure 4**). The bending line was assessed by considering the crossing of the x-z axes as the zero point of the samples; the deflection was then measured on a single point at increasing distances from the zero position.

By considering the measured deflection values (y), the following equation for the deflection occurring on both sides of the zero position was obtained:

$$y = a \cdot z_n^2, \qquad (2)$$

where a is the maximum deflection determined by minimizing the mean-square deviation of the measured and calculated values, and $z_n = z/L$ is the relative distance from the sample axis. The deflection is symmetrical about the zero point.

This form of bending corresponds to a symmetrical cantilever bending with respect to the transversal axis (**Figure 4**), with the point 0 exactly in the middle of the length 2L and the transverse axis connecting two rigidly clamped points with a positive and negative segment of the variable z_n on the left- and right-hand sides.

The measured and calculated curves for the bending of the shot-peened sample S2 are shown in **Figure 5**. The similarity of both curves, as well as the square errors approximation, confirms that equation (1) describes the bending line well.

When layers of metal are removed from the shot-peened surface the stress distribution changes and

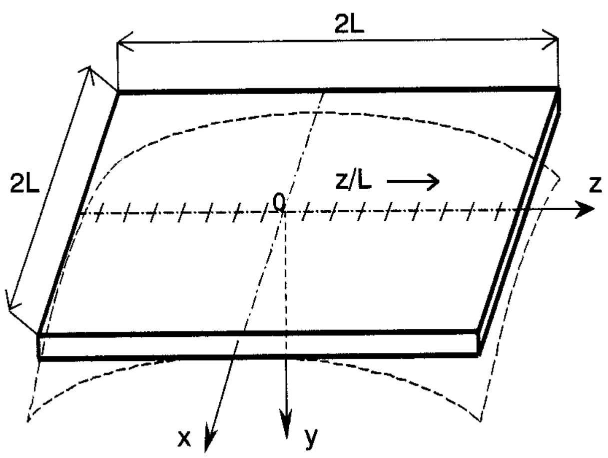

Figure 4: Elastic-plastic bending of the shot-peened sheet
Slika 4: Elasto-plastični upogib peskane pločevine

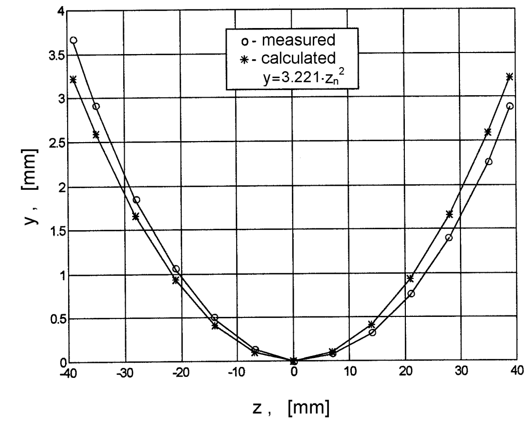

Figure 5: Measured and calculated bending line of the shot-peened sample S2
Slika 5: Izmerjena in izračunana upogibna linija vzorca S2

causes the sample to relax, which results in a decrease of the elastic bending. The bending lines calculated with equation (1) from the initial state to the state after the removal of successive layers are shown in **Figure 6**. The approximate average square error remains acceptable after the removal of each layer (**Table 4**).

It should be emphasized that the approximation of the MSE depends on fixing the sample correctly and an accurate determination of the zero position. If the zero position is changed (**Figure 5**), the MSE also has to be recalculated.

4.3 Position of the neutral section

For a correct calculation of the residual stresses due to the shot peening in the stress distribution with respect to depth must be known, and this depends on the neutral section position. An experimental-analytical method has been applied for the calculation of this position.

It has already been explained that the residual bending stresses correspond to the cantilever-bending

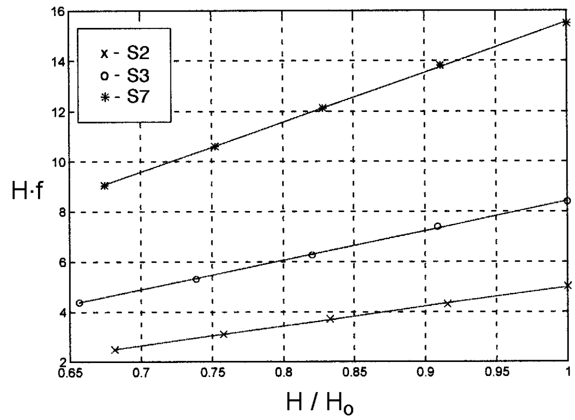

Figure 7: The dependence H·f = *f*(H) with reference to the relative value H/H_o for shot-peened samples and after the removal of successive layers
Slika 7: Odvisnost H·f = *f*(H) glede na relativno razmerje H/H_o za peskane vzorce in po odvzemu zaporednih plasti

model with the stress on surface σ_p proportional to H·f/L^2. If L = constant, then $\sigma_p \sim$ H·f.

By decreasing the sample thickness with the removal of successive layers the thickness of the stressed zone and the bending moment are decreased and a decrease of the bending is achieved. If the bending is measured after the removal of a layer of metal the dependence H·f = *f*(H) remains representative for the stress change on the surface after the removal of successive layers as well as for the neutral section position.

The linear dependence H·f = *f*(H) with a high correlation coefficient (**Figure 7**) was deduced. The H axis is shown as a relative value with regard to the starting height H_o. The intersection of the straight line H·f = *f*(H) with the H axis corresponds to the condition $\sigma_p = 0$ and its position determines the neutral section. These positions are very near to 0.6 H_o, 0.7 H_o and 0.8 H_o for the S2, S3 and S7 samples, respectively. Since these samples have a different surface coverage, the neutral section can also be determined for other samples with a coverage value in the range of specimens S2 to S7.

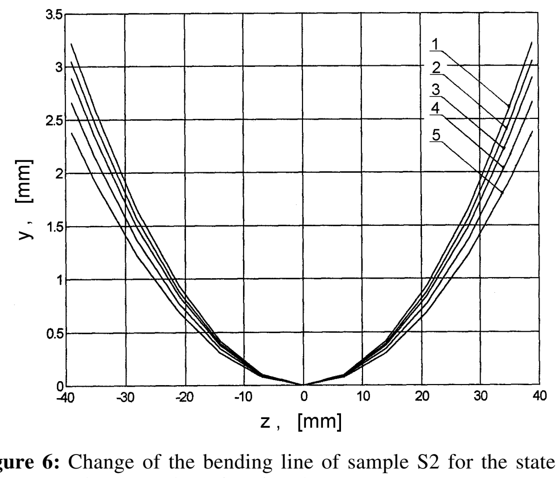

Figure 6: Change of the bending line of sample S2 for the state (1) after successive removing of surface layers
Slika 6: Sprememba upogibne linije vzorca S2 po zaporednem odvzemu površinskih plasti

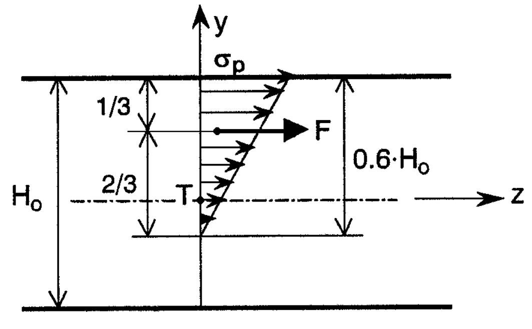

Figure 8: Linear distribution of the residual stresses with the neutral surface at 0.6 H_o for the initial state
Slika 8: Linearna porazdelitev rezidualnih napetosti pri nevtralni ploskvi pri 0,6 H_o za začetno stanje

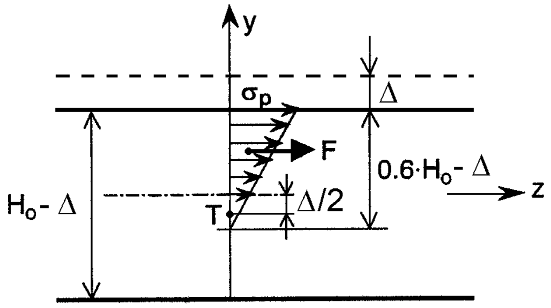

Figure 9: Linear distribution of the residual stresses with the neutral surface 0.6 H_o after removal of a layer of thickness Δ
Slika 9: Linearna porazdelitev rezidualnih napetosti pri nevtralni ploskvi pri 0,6 H_o po odvzemu plasti z debelino Δ

4.4 Derivation of the equation for the residual stresses

Stress-distribution model on sheet section

For the calculation of the residual stresses it is necessary to know the neutral section position and the mode of stress distribution. A linear stress distribution was assumed because it is relatively simple. The scheme of the sample load with the neutral section at the depth 0.6 H_o is shown in **Figure 8**.

The distribution function of the residual stresses has the following form:

$$\sigma_z = \sigma_p \left[A_1 h_r + A_2 \right] \tag{3}$$

where: σ_p - near-surface stress (MPa);
h_r - relative thickness (h/H_o);
A_1, A_2 - constants.

The unknown constants are determined after considering the boundary conditions:

- for the maximum stress on the surface ($h_r = 1/2$; $\sigma_z = \sigma_p$);
- for the space balance on a sample of length B = 2L ($\int_0^B \int_{-7/10}^{1/2} \sigma_z dBdh_r = 0$).

The solutions for known constants make it possible to represent the linear distribution of residual stresses in the form:

$$\sigma_z = \sigma_p \left[\frac{10}{6} h_r + \frac{1}{6} \right] \tag{4}$$

The bending model

As already mentioned, the deformation of shot-peened samples corresponds to a cantilever symmetric bending with respect to the transverse axis. As the stresses are constant on the sample, the bending moment is also constant and the relation for the cantilever bending moment is:

$$M_b^c = \frac{2EI_x}{L^2} f_{el} \tag{5}$$

where: E - elastic modulus (MPa);
I_x - the inertia moment for the x axis (mm^4);
f_{el} - the maximum value of the elastic deflection (mm);
L - the cantilever length (half of the sample length) (mm).

The bending conditions are related to the residual stresses by the equation:

$$M_b^{rs} = \int_{-H_0/10}^{H_0/2} \sigma_z Bhdh \tag{6}$$

The surface stress is then defined from the equality of moments deduced from the relations (5) and (6):

$$\sigma_p = \frac{50}{27} \frac{EH_0}{L^2} f_{el} \tag{7}$$

During the removal of layers the residual stresses are determined with reference to the newly formed surface according to the loading scheme given in **Figure 8 and 9**. The loading moment is then:

$$M_b^{rs} = F \cdot Y \tag{8}$$

where:
$F = \frac{1}{2}(0{,}6H_0 - \Delta)\sigma_p B$ - the force due to the residual stresses;
$Y = \left[\frac{2}{3}(0{,}6H_0 - \Delta) - 0{,}1H_0 \right] + \frac{\Delta}{2}$ - the distance from the action point of the force (F) to the focus T.

The final formula for the transversal residual stress on every newly formed surface is then deduced from the equality moments (relations 5 and 8) as follows:

$$\sigma_p = \frac{2E(H_0 - \Delta)^3 f_{el}}{3H_0^2 L^2 \left[\left(\frac{3}{5} - \frac{\Delta}{H_0} \right) \left(1 - \frac{5}{3} \frac{\Delta}{H_0} \right) \left(\frac{3}{5} - \frac{1}{3} \frac{\Delta}{H_0} \right) \right]} \tag{9}$$

For the starting state with Δ = 0 this equation becomes identical to equation (7). Equation (9) was deduced for the neutral section position in position 0.6 H_o. For the other two positions the calculation is analogous and their equations are shown in **Table 6**.

4.5 Elasto-plastic bending

To define the residual stresses according to the relations in **Table 6** it is necessary to know the elastic deflection line. After shot peening all the samples an elastic-plastic bending occurs and it is necessary to separate these two components for a measured deflection. This separation is possible if the yield stress is known. Being in an isotropic stress state[2,3] the residual achieves the plastic yield stress when any of these two plane components reach the yield stress in a sheet thickness that is nearly equal to the yield strength of the alloy (134.7 Mpa).

Considering this condition the values of maximum elastic bending preceding the plastic deformation were calculated using the equation in **Table 6** (σ_p for the starting state). The obtained values of 1.24 mm and 1.28 mm agree with the position of the neutral section (**Table**

Table 6: Relations for the calculation of the transversal residual stresses
Tabela 6: Odvisnosti za izračun prečnih zaostalih napetosti

Position of neutral surface	Equation for linear distribution	σ_p for initial state	σ_p after removing of layer thicknes Δ
$0.6H_o$	$\sigma_z = \sigma_p\left[\frac{10}{6}h_r + \frac{1}{6}\right]$	$\sigma_p = \frac{50}{27}\frac{EH_0}{L^2}f_{el}$	$\sigma_p = \frac{2E(H_0-\Delta)^3 f_{el}}{3H_0^2L^2\left[\left(\frac{3}{5}-\frac{\Delta}{H_0}\right)\left(1-\frac{5}{3}\frac{\Delta}{H_0}\right)\left(\frac{3}{5}-\frac{1}{3}\frac{\Delta}{H_0}\right)\right]}$
$0.7H_o$	$\sigma_z = \sigma_p\left[\frac{10}{7}h_r + \frac{2}{7}\right]$	$\sigma_p = \frac{25}{14}\frac{EH_0}{L^2}f_{el}$	$\sigma_p = \frac{2E(H_0-\Delta)^3 f_{el}}{H_0^2L^2\left[\left(\frac{7}{10}-\frac{\Delta}{H_0}\right)\left(1-\frac{10}{7}\frac{\Delta}{H_0}\right)\left(\frac{4}{5}-\frac{1}{2}\frac{\Delta}{H_0}\right)\right]}$
$0.8H_o$	$\sigma_z = \sigma_p\left[\frac{10}{8}h_r + \frac{3}{8}\right]$	$\sigma_p = \frac{25}{14}\frac{EH_0}{L^2}f_{el}$	$\sigma_p = \frac{2E(H_0-\Delta)^3 f_{el}}{H_0^2L^2\left[\left(\frac{4}{5}-\frac{\Delta}{H_0}\right)\left(1-\frac{5}{4}\frac{\Delta}{H_0}\right)\left(\frac{7}{5}-\frac{\Delta}{H_0}\right)\right]}$

2). The relative share of the plastic deflection was obtained as a difference up to 1. The differences in the surface coverage of the examined samples cause differences in the total bending, as well as in the share of the elastic and plastic components. This share changes from 0.38 to 0.62 in the sample (S1) with the minimum coverage; up to 0.1 to 0.9 in the samples with the maximum coverage (S8). These results show that the induction of residual stresses by the shot-peening process with our chosen parameters is very intensive; with a time of 5 sec the induced stresses reach the yield point and cause a considerable plastic deformation.

After the removal of successive layers of metal the surface stresses are successively decreased. The elastic loading moment and the elastic stress component decrease, while the plastic component remains unchanged (**Table 4**). Consequently, the residual stresses remaining in the sheet will decrease below the yield stress.

4.6 Stress level

The calculated stress on the new surface (**Table 4**) decreases in relation to the total thickness of the removed metal (**Figure 10**). For the assumed linear distribution, the stresses on a shot-peened sheet surface can be obtained at the point $\Delta = 0$. The stresses on the surface of the samples S3 and S7 remain at the level of the sheet yield strength shot peened for 15 sec (~160 MPa) and are higher for the sample S2 (186.2 MPa). The values of stresses at the surface, obtained with x-ray diffraction of samples of the same alloy with a coverage of 200 %, are 220 MPa [4].

The plastic deformation significantly affects the residual stresses and high stresses are also induced for short shot-peening times. The residual stresses isotropy was determined on round samples by comparing the maximum deflection in two mutually orthogonal directions - RD and TD. The results show that the isotropy is conserved up to a surface coverage of ~90 %,

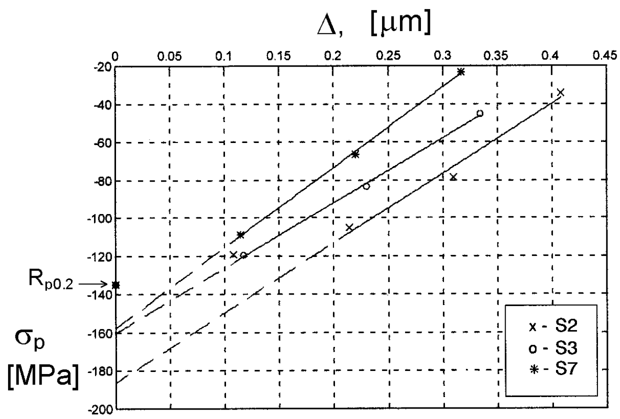

Figure 10: Surface stress σ_p in relation to the total thickness of the removed layer for the samples S2, S3 and S7

Slika 10: Površinska napetost σ_p v odvisnosti od debeline odvzete plasti za vzorce S2, S3 in S7

at this point the share of the elastic and plastic deflections increases from 0.23 to 0.77.

The anisotropy of the yield stress of the sheet is ~3 % ($\Delta R_{p0.2}$ = 4.08 MPa) and the yield stress is higher in the rolling direction. After shot peening there is no effect of the anisotropy of the mechanical properties and the bending anisotropy is related only to the shot-peening conditions. Differences could occur because of the variation of the shot stream and the sample condition, which are kept constant. The isotropy is real even for large plastic deformations and print depths on the sheets of great thickness.

5 CONCLUSIONS

The investigation of sheet samples of the alloy AlMg4.5Mn after shot peening with balls of 700 μm diameter showed that the depth of the obtained prints is in the range of 34 to 170 μm with a level of surface coverage equal to 95 % after 25 s, and of > 100 % after 35 s of shot peening.

High residual stresses are induced and the elastic-plastic bending of the examined sheet occurs. The bending can be approximated by a second-order polynomial for a bend cantilever. The stress level induced can produce plastic deformation of the sheet.

The maximum stress values at the surface are close to the yield stress of the alloy (~160 to 185 MPa) and their neutral position is at a depth of 0.6-0.8 H_o.

The isotropy of the stresses is acceptable up to a coverage of ~90 % with the ratio of elastic and plastic deflections of 0.23 to 0.77, and it is reliable for the elastic zone.

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