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MECHANICAL AND CORROSION PROPERTIES OF ALUMINIUM ALLOY EN AW 6082 AFTER SEVERE PLASTIC DEFORMATION (SPD)

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Preliminary Note – Prethodno priopćenje

The aim had been to study changes in the properties of aluminium alloy AlSiMgMn. Influence of SPD of the mechanical properties had increased (R_m by 86 MPa, $R_{p0,2}$ by 175 MPa, while A had decreased to 20 %). The corrosion potentials had been evaluated in the environment of H_2O and in SARS. After SPD was observed in the environment of H_2O, that resistance had increased by -218 mV and after exposure up to 1 000 min there was a slight deterioration of resistance in SARS. On the surface specimens after SPD were observed higher quantities of corrosion products. After SPD was observed fatigue characteristics in torsional stress in the oblique branches Wöhler curves showed favourable characteristics of about 35 %.

Key words: aluminium alloy, severe plastic deformation, mechanical properties, corrosion properties, fatigue properties

INTRODUCTION

In presence the aluminium alloy AlSi1MgMn belonging to Classes 6XXX, often used as construction material for the automotive, aerospace, shipping and construction industries. Generally, aluminium alloys are used because of their low specific weight achieves good mechanical and fatigue properties. Aluminium alloy are having resistance in the atmospheric conditions towards to corrosion degradation with the formation of the protective oxides layer possibly hydroxides of aluminium [1-3].

At a molar ratio of Mg / Si greater than 1,73 are not susceptible to intergranular corrosion, which is caused by a small potential difference between the Mg_2Si particles and the matrix [4-5].

Significant improvement in these properties can be achieved by combining appropriately chosen heat treatment followed by intensive plastic deformation through technology ECAP (Equal Channel Angular Pressing). ECAP technology lies in extruded the alloy through a die consisting of two at each perpendicular channels without changing the cross-sectional sample. Improvement in mechanical properties is the result of obtaining structure with ultra-fine grain size below 10 microns and precipitation hardening Mg_2Si particles during aging after intensive plastic deformation [6-8].

The aim of the article is to assess the impact of intense plastic deformation on mechanical, fatigue and corrosion properties.

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MATERIAL AND EXPERIMENTAL METHOD

As experimental material was used aluminium alloy EN AW 6082 (AlSi1MgMn) in the initial state T4 (solution annealing and natural ageing) and in state after intensive plastic deformation prepared by ECAP for the heat treatment (solution annealing at 550 °C / 1,5 h + water quenching at room temperature + 3 x ECAP artificial ageing of 100 °C / 30 h). The chemical composition of the aluminium alloy is shown in Table 1.

Table 1 **Chemical composition of Al alloy EN AW 6082 /wt. %**

Al	Cu	Si	Mg	Mn	Fe
93,46	4,37	0,52	0,74	0,65	0,26

The mechanical properties were measured by a static tensile test at room temperature on the machine ZWICK 1387, in initially state and state after ECAP are shown in Table 2.

Table 2 **Mechanical properties of aluminium alloy**

Materials	Mechanical properties			
	$R_{p0,2}$ / MPa	R_m / MPa	Z / %	A_5 / %
Initial state	190	298	51	22
ECAPed state	365	384	39	20

From the measured values of strength characteristics after intensive plastic deformation strength of yield had increased up to 92 %, ultimate strength had increased up to 28 %, while the elongation decreased down to 24 % and contraction had decreased in 10 % compared to the initial state.

Open circuit potentials (OCP) were measured by using a digital multimeter Agilent 34405 DMM in a solution of distilled water and SARS, whose chemical composition are shown in Table 3. Measurement was carried out by two electrodes connections, which consisted working electrode (sample testing of materials) and reference saturated calomel electrode (SCE).

Table 3 **Chemical composition of solution SARS / mMol/l**

HNO_3	NaCl	$(NH_4)_2SO_4)$
0,01	1	1

The corrosion characteristics of the samples were evaluated in its initial state and the state after ECAP. Mark of samples is showing Table 4.

Table 4 **Mark of samples**

Mark of samples	State	Environment
A	initial	distilled water
B	initial	SARS
C	ECAPed	distilled water
D	ECAPed	SARS

Dependence of open circuit potentials E_{SCE} after exposure time from 1 min to 263 520 min are graphically shown in Figure 1 showing dependence of open circuit potentials for samples A and C, Figure 2 for samples B and D.

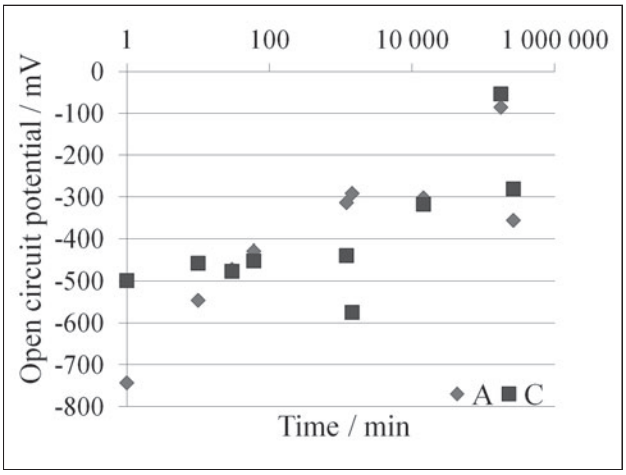

Figure 1 Dependence of OCP on the exposure time of samples in distilled water

Figure 1 is showing, that sample A has a tendency to shift the positive open circuit potential, while the samples C are having steady open circuit potential from the start of exposure. In both cases, exposure took 175 680 min. There was noticed fluctuation in open circujt potentials, where can be expected creation of a passive film on the surface. Open circuit potential after 263 520 minutes long exposure, had decreased to the level of exposure reached at 14 400 min long exposure.

Same results as we had with distilled water also occured in the SARS solution Sample B at the initial state

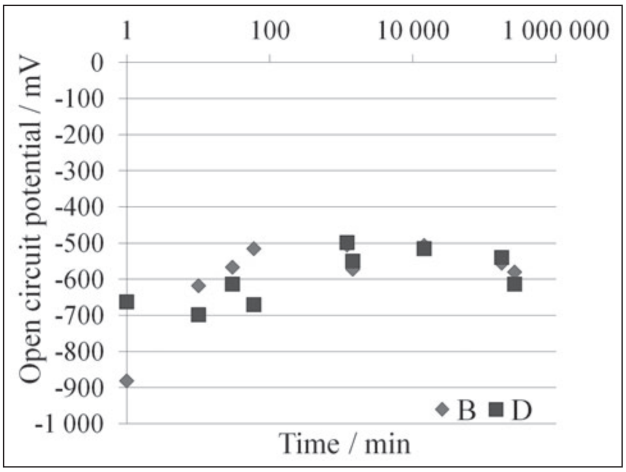

Figure 2 Dependence of OCP on the exposure time of samples in SARS

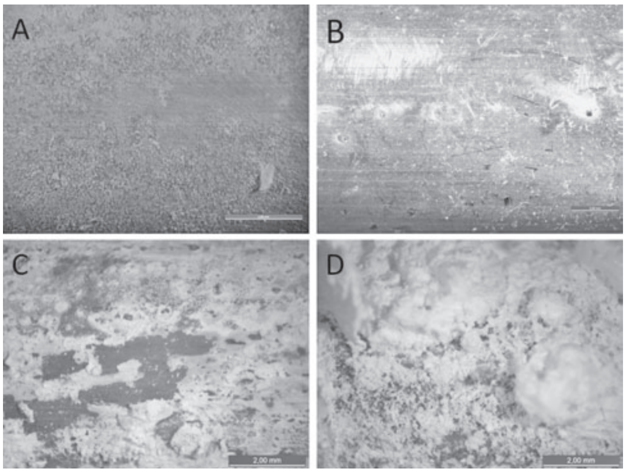

Figure 3 The surface of samples after exposure (263 520 min)

of exposure showed potential displacement of + 366 mV. On the other hand samples B and D showed stabilization of the open circuit potential after 14 400 minutes long exposure.

The surface of samples after exposure (263 520 min.) are documented on Figure 3.

The surfaces of samples A and B were not significantly affected, on the other hand, samples C and D were coated with a layer of white corrosion products. According to the EDX analysis, corrosion products for samples C and D, after exposure (263 520 min long) were on the basis of sulphates and chlorides of Ca, Fe, Zn and Al.

Fatigue properties of the torsional load for the aluminium alloy EN AW 6082 were evaluated on samples from the initial state and the state after ECAP at a frequency of 35 Hz. Diagonal branches Wöhler dependence is documented on to Figure 4.

Following the inclination of the oblique branch Wöhler curve, can be stated that after intensive plastic deformation was increased the fatigue resistance.

The time endurance strength at the number of fatigue cycle's $\tau_{c10}{}^4$ is in the initial state 220 MPa and 260MPa in the state after ECAPed. With more than $\tau_{c10}{}^5$

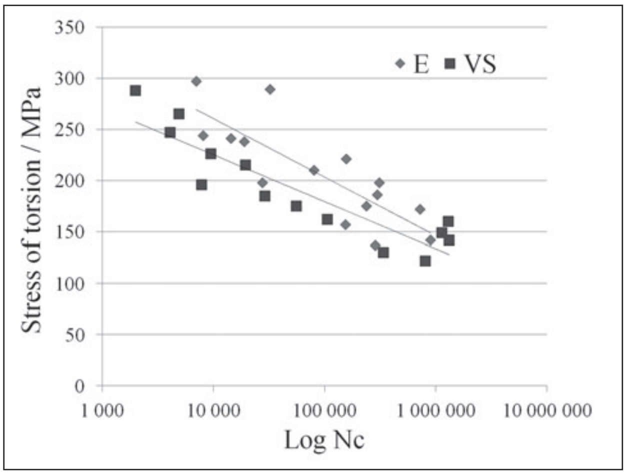

Figure 4 Diagonal branch of the Wöhler curve

cycle´s, the time endurance strength is in the initial state 180 MPa and 200 MPa in the state after ECAPed.

The value ratio from between endurance strength and ultimate tensile strength (τ_{cx}/R_m) are shown in Table 5.

Table 5 **Fatigue characteristics**

State	τ_c/R_m	
	10^4	10^5
Initial	0,738	0,604
ECAPed	0,677	0,520

From the measured values shown in Table 5 can be seen that increasing in number of cycles is the ratio endurance strength decreasing in both states of the aluminium alloy.

It is given by parametric equation, which applies, that if there is higher ultimate tensile strength, than the ratio of the endurance strength is lower.

Failure fracture the samples in both states takes the place in the direction perpendicular to the axis of the sample, where the initiation took the place from the surface to the interior of the material.

CONCLUSIONS

In the article was analyzed influence of intensive plastic deformation on the mechanical, corrosion and fatigue properties of aluminim alloy EN AW 6082 (AlSi1MgMn) compared to initial state alloy.

- The strength characteristics of the static tensile test after ECAP increased from initial state, the yield strength by 92 %, ultimate strength by 28 %, while the elongation decreased by 24 % and contraction by 10 %.
- In the exposure of distilled water sample A shows a shift the positive open circuit potential unlike sample C which achieves stable open circuit potential.
- In the solution SARS samples B and D achieved stabilization open circuit potential after exposure to 14 400 min.
- The surfaces samples A and B after exposure were not significantly affected. Samples C and D were covered with a layer corrosion products that have created effective protection against corrosion degradation.
- In addition to the yield strength and tensile fatigue properties also increased after intensive plastic deformation, despite a slight reduction in plastic properties.

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Note: The responsible translator for English language is Andrea Horvath, Prievidza, Slovakia