

Studies of corrosion behaviour in alkaline environment of binary Mg-Li alloys for plastic forming

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Abstract

The article discusses studies and corrosion tests of binary Mg-Li alloys for plastic forming examined in an alkaline medium (5% NaCl solution) for the time of 0-144 hours. In short it can be stated that the increase of Li content in magnesium alloys from 3% to 9% increases the corrosion resistance of alloy (the lowest susceptibility to corrosion in NaCl solution showed Mg-Li9 alloy). Increasing the content of Li in alloy to over 9% resulted in a significant increase of the susceptibility to corrosion.

Keywords: Ultralight Mg-Li alloys, Corrosion in alkaline media

1. Corrosion tests of Mg-Li alloys in alkaline medium

The object of corrosion studies were as-cast samples of Mg-Li alloys of 30 x 20 x 10 mm dimensions designated as:

- alloy no. 1 containing 3,54% Li (monophase α hcp alloy),
- alloy no. 2 containing 8,15% Li (two-phase alloy; β phase and $\alpha+\beta$ eutectic), alloy no. 3 containing about 13,9% Li (monophase β bcc alloy).

Laboratory tests of the corrosion behaviour of Mg-Li alloys were carried out by immersion of samples at ambient temperature,

according to the following standards: PN-76/H-04601, PN-78/H04610, PN EN ISO 16151. The principle of the method consisted in subjecting the samples of Mg-Li alloys to the effect of a solution prepared in a laboratory. The immersion test was conducted in 5% aqueous solution of NaCl. To prepare this solution, analytically pure chemical reagents and redistilled water were used. The duration of individual measurement cycles was 6 h, 24 h, 48 h, 72 h and 144 h.

Samples of the examined alloys (3 samples from each melt) were subjected to corrosion tests in accordance with the adopted programme of research. Figures 1 and 2 show in graphic form the results of corrosion-induced weight loss and corrosion rate.

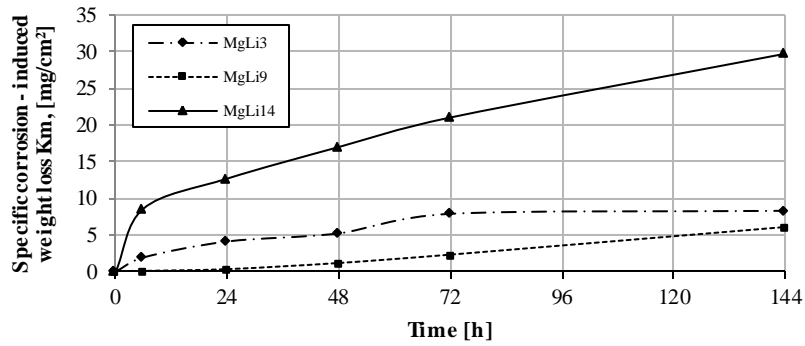


Fig. 1. Comparison of the results of the corrosion-induced weight loss test carried out for Mg-Li alloys in 5% NaCl solution – specific corrosion-induced weight loss in time

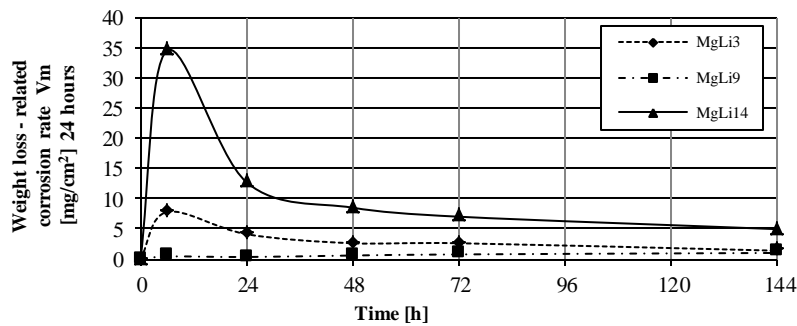


Fig. 2. Comparison of the results of the corrosion-induced weight loss test carried out for Mg-Li alloys in 5% NaCl solution – weight loss-related corrosion rate V_m in time

Figures 3-4 show surface condition of samples of the tested alloys after 6, 72 and 144 hours of being immersed in 5% NaCl solution.

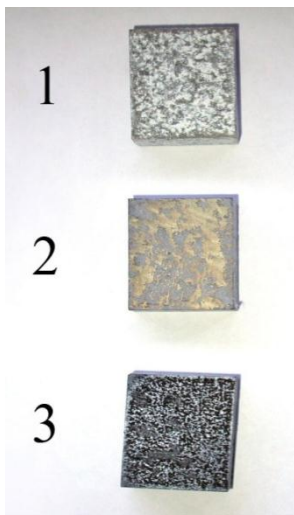


Fig. 3. Surface condition of the samples of the examined Mg-Li alloys after 6 h of being immersed in 5% NaCl solution

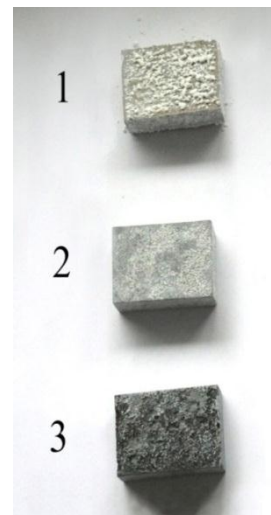


Fig. 4. Surface condition of the samples of the examined Mg-Li alloys after 72 h of being immersed in 5% NaCl solution

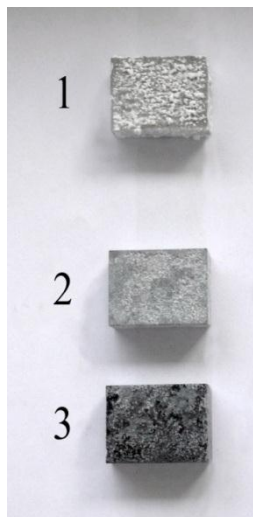


Fig. 5. Surface condition of the samples of the examined Mg-Li alloys after 144 h of being immersed in 5% NaCl solution

Macrographic studies were also carried out on the precipitates of reaction products on the surface of the examined alloy samples. Figures 6-8 show selected examples of the surface topography of the examined alloys.



Fig. 6. Surface topography of alloy 1 sample (after 6 h of being immersed in 5% NaCl solution, 7x)



Fig. 7. Surface topography of alloy 2 sample (after 6 h of being immersed in 5% NaCl solution, 7x)



Fig. 8. Surface topography of alloy 3 sample (after 6 h of being immersed in 5% NaCl solution, 7x)

2. Summary

Studies of the weight loss-related corrosion of Mg-Li alloys show an increase in the specific corrosion-induced weight loss K_m in time in the case of all the tested samples, the largest weight loss having been found in alloy with the highest content of lithium, i.e. in Mg-Li14 alloy (alloy no. 3), which is illustrated in Figure 1. The smallest weight loss was observed in a two-phase Mg-Li8 alloy (alloy no. 2). As results from Figure 2, the rate of the weight loss-related corrosion V_m for alloy no. 3, i.e. Mg-Li14, increased significantly in the first measuring cycle (6 h) and was 4.4 - fold higher than for alloy No.1. In subsequent measuring cycles (24 h, 48 h, 72 h, 144 h), the rate of the weight loss-related corrosion decreased for these alloys. On the other hand, in the case of the two-phase Mg-Li8 alloy, the weight loss-related corrosion rate increased slightly in the first measuring cycle (6 h), then slightly decreased after 24 h of the corrosive medium effect, to slightly increase again in the subsequent measuring cycles.

An analysis of the alloy sample surface showed that in alloy no. 1 (Mg-Li3,5) corrosion was spread evenly on the entire sample surface. The sample surface was coated with white, grainy bloom. The Mg-Li8 alloy showed evenly distributed corrosion, and the sample surface was covered with white, fine grains. In Mg-Li14 alloy, the corrosion was distributed unevenly, the surface was covered with black and white bloom. Numerous pits were also observed to occur.

It was noted that after a short time of being held in an aqueous solution of NaCl, the surface of pure magnesium was covered with a thin coating. An analysis of this coating showed that it was composed of rapidly combining MgO and MgCl₂. With prolonged exposure to the corrosive effect of an alkaline medium, the next bonds were formed giving MgH₂ and Mg(OH)₂. These coatings had a passivating effect, but the mechanism of their operation was not the same as in the case of aluminium, because they had relatively high porosity (pore volume) (MgO), or caused defects in the crystal lattice of Mg², leading to the formation of compressive stresses in the coating, finally threatening the coating detachment from the substrate. This phenomenon was particularly frequent in the case of Mg(OH)₂.

Summing up, it has to be stated that an increase in the lithium content in magnesium alloys from 3% to 9% increases the

corrosion resistance of alloy (the lowest susceptibility to corrosion in NaCl solution showed the Mg-Li8 alloy). On the other hand, increasing the content of Li above 9% significantly increases the susceptibility to corrosion. These results allow concluding that the presence of lithium causes the formation of a thin film, which is more durable than pure magnesium and, considering the alkaline medium of corrosion, the coating is composed, at least partially, of LiCl. In the case of binary alloys with high lithium content, a rapid formation of the coating is observed, but it can be expected that starting with certain critical concentration of lithium, an intense reaction will proceed on the surface, while products of this reaction will not be capable of arresting further course of the reaction taking place between the metal surface and the corrosive medium.

In addition to the formation of a coating, which is considered a type of surface corrosion, a local corrosion occurs, too. These corrosion phenomena observed at a macro level on the surface can be qualified, first of all, as a pitting or intergranular corrosion. Local corrosion phenomena can be associated with precipitation effect as well as other types of effects such as a heterogeneous structure, which may be due to different electrochemical potentials of the structural constituents.

The observed local corrosion effects can be reduced by forming a homogeneous structure or by adding elements characterised by small difference of electrochemical potentials compared with the base binary alloy.

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