MECHANICAL PROPERTIES OF ZN-MG ALLOYS

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Abstract

Both magnesium and zinc are considered as suitable elements for preparation of biodegradable materials that can be gradually dissolved in human organism without the production of toxic compounds. Although many magnesium-based materials possess good mechanical properties and biocompatibility, corrosion rates accompanied by hydrogen release and pH increase are too high. On the contrary, Zn is characterized by much lower corrosion rate in physiological solution compared to magnesium and its alloys. Therefore, we study Zn-Mg binary alloys with 0-7 wt.% of Mg. In this case, magnesium was selected to improve mechanical properties and biocompatibility of pure Zn. The structures of alloys were studied by an optical metallographic microscope and SEM equipped with EDS analyzer. Mechanical properties were studied using Vickers hardness measurements, compressive tests, tensile tests and bending tests. Our results showed that mechanical properties of binary Mg-Zn alloys improve with increasing content of Mg, achieving the maximum at eutectic composition. Higher Mg concentrations strongly deteriorate mechanical properties of binary Mg-Zn alloys.

Keywords: zinc, biodegradable material, microstructure

1. INTRODUCTION

Science is currently spending a lot of time and effort in research of biodegradable materials that are used in the human body. Polymers are already commonly used to repair various tissues. When used as fixatives they do not have suitable mechanical properties. Another possible solution for these applications consists in the studied metallic materials based on magnesium. Magnesium is non-toxic to the human body [1]. However, its utilization also brings some negative effects. First one is a very high corrosion rate [2]. A by-product of the degradation of Mg alloys is hydrogen. In the vicinity of the metal, implant creates an alkaline environment. These negative effects impair the healing process. Therefore, research is also dedicated to testing possible other alloys, which will exhibit acceptable corrosion rate and their composition will not harm the human body [3]. Zinc base alloys appear to be suitable for this application. Zinc metal is more noble than magnesium. This implies that the corrosion rate will be smaller with less hydrogen evolution. Zinc is also non-toxic to the human body and has greater strength. Mechanical properties are likely to be better than for magnesium alloys [4]. Zinc alloys are also less costly to prepare. They are prepared at lower temperatures and do not require the protective atmosphere during processing.

2. EXPERIMENT

For this research, following alloys of zinc were chosen: pure Zn and Zn-Mg alloy containing up to 7 wt. % Mg (ZnMg0.5; ZnMg1; ZnMg2; ZnMg3, ZnMg5; ZnMg7). The composition was designed according to the phase diagram to obtain the hypoeutectic, eutectic and hypereutectic alloys. The chemical composition in as-cast state was checked by X-ray fluorescence spectroscopy, as shown in Table 1.
Tab. 1 Chemical composition of the investigated Zn-based alloys

<table>
<thead>
<tr>
<th>Alloys designation</th>
<th>Element (wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
</tr>
<tr>
<td>Zn</td>
<td>99,97</td>
</tr>
<tr>
<td>ZnMg0.5</td>
<td>99,10</td>
</tr>
<tr>
<td>ZnMg1</td>
<td>98,38</td>
</tr>
<tr>
<td>ZnMg2</td>
<td>97,35</td>
</tr>
<tr>
<td>ZnMg3</td>
<td>96,49</td>
</tr>
<tr>
<td>ZnMg5</td>
<td>93,65</td>
</tr>
<tr>
<td>ZnMg7</td>
<td>91,64</td>
</tr>
</tbody>
</table>

Before identification of the mechanical properties, metallographic samples of cast alloys were prepared. Then the structure of the materials was observed using a light metallographic microscope (Olympus PME-3) and TESCAN VEGA 3 LMU scanning electron microscope with EDS analyser (Oxford Instruments). Mechanical properties were characterized by Vickers hardness (HV5) and compression tests performed at room temperature (LabTest 5,250SP1-VM).

3. RESULTS AND DISCUSSION

3.1 Structure
Structure of prepared alloys can be seen in the figures below. Fig. 1a presents the microstructure of pure zinc. It consists of relatively large grains whose size is caused by slow cooling during solidification. In Fig. 1b-1d, ZnMg0, 0,5, ZnMg1, ZnMg2 hypoeutectic alloys can be seen as the primary Zn-based solid solution dendrites (light) and eutectic mixture of Zn and Mg2Zn11 (dark). With increasing content of magnesium, the proportion of eutectic grows. Fig. 1e shows the ZnMg3 eutectic alloy, being composed of a mixture of Zn and Mg2Zn11. In Figure 2f and 2g, there are structures of hypereutectic alloys ZnMg5, ZnMg7.
3.2 Mechanical properties

The values of Vickers hardness and compressive strength values are summarized in Table 2. Hardness of the alloys depends on the amount of formed Mg2Zn11 phase.

With the growing magnesium content, the material’s hardness increases. The compressive strength was evaluated only for the alloys with lower magnesium content. Although hypereutectic alloys have greater hardness, they are fragile and loading lead to their damage.

<table>
<thead>
<tr>
<th>Testing alloys</th>
<th>Vickers hardness</th>
<th>Compressive strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>37</td>
<td>300</td>
</tr>
<tr>
<td>ZnMg0.5</td>
<td>80</td>
<td>640</td>
</tr>
<tr>
<td>ZnMg1</td>
<td>82</td>
<td>490</td>
</tr>
<tr>
<td>ZnMg2</td>
<td>102</td>
<td>800</td>
</tr>
<tr>
<td>ZnMg3</td>
<td>124</td>
<td>860</td>
</tr>
<tr>
<td>ZnMg5</td>
<td>196</td>
<td>300</td>
</tr>
<tr>
<td>ZnMg7</td>
<td>226</td>
<td>110</td>
</tr>
</tbody>
</table>

Fig. 1 Optical micrographs of alloys based on zinc
With the growing magnesium content, the hardness of the materials increases. The compressive strength was evaluated only for the alloys with lower magnesium content. Although hypereutectic alloys have greater hardness, they are fragile and loading lead to their damage.

4. CONCLUSIONS

This work describes the microstructure of Zn-based alloys. The structure significantly changes with increasing magnesium content. The values of hardness and compressive strength increase with growing content of magnesium, due to the formation of Mg2Zn11 phase. Hypoeutectic Zn-Mg alloys were proved to be suitable materials for further research. Hypereutectic alloys are too fragile for the desired biomedical applications.

ACKNOWLEDGEMENTS

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REFERENCES