CHARACTERISTICS OF MICROSTRUCTURE AND PROPERTIES OF MAGNESIUM ALLOYS SHAPED WITH THE USE OF METHOD IN COMPLEX STATE OF STRAIN

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Abstract

The article presents the tests results which tested the possibilities of shaping magnesium alloys. Testing materials were ingots from magnesium alloys with symbols LAE442 (Mg-Li 4%) and WE43. One of the aims of conduction of plastic shaping tests with the use of KOBO method was to achieve a product in the form of flat bars. The paper presents the results of mechanical tests of tested alloys marked in a uniaxial tension test in room temperature and in elevated temperature for achieved flat bars. Fractographic tests were conducted in tension test in order to determine the mechanism of cracking. A microstructure analysis was conducted both in the initial condition and in condition after plastic strain with the use of techniques of light microscopy and scanning microscopy.

Keywords: Magnesium alloys, microstructure, tensile test, fractography, hot deformation

1. INTRODUCTION

The basic criterion for application of modern construction materials is their high value of proper strength presented as the ratio of resistance to tension and the density of the given material. Application of magnesium alloys for construction elements used in means of transport production has led the conduction of intensive tests of those materials [1-5]. It is mainly connected with continuous search for a material which will reduce the weight of the vehicle and replace the conventional materials. Since the 1950s, the interest in magnesium alloys for construction elements has been growing. Magnesium alloys started to be applied mostly in automotive industry as well as car and machine industry. At present, lots of tests are being performed in order to use those materials in aviation industry. Due to the application of magnesium which has density of 1.74 g/cm^3, the weight of the product is decreased by 30% [6-7]. Additionally, the increase of susceptibility to plastic shaping of magnesium alloys may be provided by lithium addition in the amount of 15% of the weight of the alloy. At the same time, with the introduction of lithium with density of 535 kg/m^3 a significant decrease of the weight of the material is achieved [8, 9]. Because of the high application potential, the magnesium alloys with lithium are currently being analysed to a very advanced extent. It should be pointed out that the drawback of the alloys with lithium in its chemical composition is the decrease of the strength of such magnesium alloys and decrease of the corrosion resistance, particularly in case of high content of lithium. It was confirmed in the paper [6] where the results are presented for the magnesium alloys with 4.5% of lithium content which is characterised with limited corrosion resistance. The scientific research conducted for those materials requires not only a lot of knowledge but also the application of the proper scientific and technological back-up facilities [7]. The article presents tests concentrated on the assessment of the possibilities of plastic shaping of magnesium alloys with the use of KOBO method [7]. The analysis of structure and changes of properties are conducted for alloys WE43, LAE442 (Mg-4% Li).

2. EXPERIMENTAL PROCEDURE

The chemical compositions of the tested magnesium alloys are shown in **Table 1**. The alloys were smelted in single-compartment vacuum induction lab furnace VSG 02 by Balzers Company. Casting was conducted in argon atmosphere. As a result of casting process the ingots were achieved with diameter of 40 mm and height of 65 mm.

Table 1 Chemical composition of the investigated alloys (mass.%)

Alloys	Li	Al	Y	RE	Zr	Mg
LAE442 (Mg-4%Li)	4	4	-	2	-	rest
WE43	-	-	4	3	0.5	rest

Test of plastic shaping of analysed alloys was conducted with the use of KOBO process in room temperature. The method is based on extrusion of the material with additional plastic deformation caused by variable torsion of matrix with respect to the product. Two different methods of extrusion were applied. The first is based on extrusion of sample with side flow of the material (**Figure 1**) and the second with concurrent flow of material (**Figure 2**) [7].

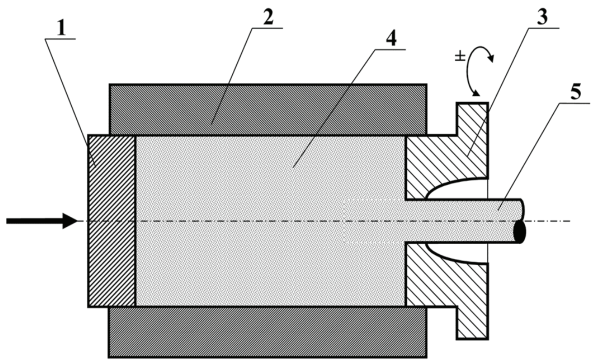


Figure 1 Diagram of direct extrusion: 1- punch, 2- container, 3- cyclic rotated die with groove on face area surface, 4- extruded material, 5- charge/product [7]

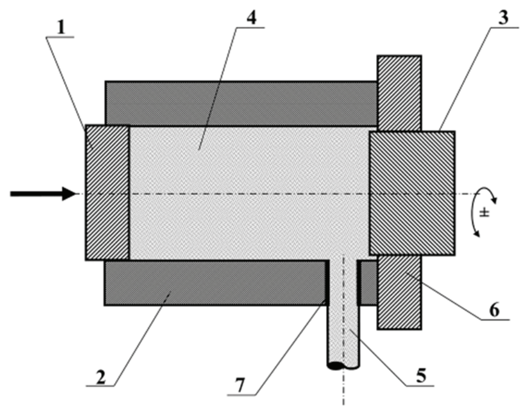


Figure 2 Diagram of extrusion with side material: 1- flow, 2- punch, 3 - container, 4-cyclic torsion, inversely finned disc extruded material/charge, 5 - product, 6- lock, 7- die opening [7]

The result of conducted tests was the achievement of flat bars with width of 12 mm and height of 4 mm for alloy LAE442 (Mg-4% Li), WE43. The analysis of structure changes in initial condition and after applied plastic deformation was conducted with the use of light microscopy and electron microscopy techniques. Test of mechanical properties of flat bars was conducted on testing machine ZWIK/Z100. Samples of tested magnesium alloys were stretched in room temperature and elevated temperature of 200°C. Hardness tests were conducted on hardness tester ZWICK type 3212002/00 in accordance with norm PN-EN ISO 6507-1/2005 with the use of Vickers method and load of 20N. Mean grain diameter was marked after extrusion process for alloy WE43 with the application of MET-ILO program [9]. Measurement of grain size was conducted with the use of surface method based on the pictures registered by light and scanning microscopes.

3. RESULTS AND DISCUSSION

Chosen microstructures of tested alloys in condition after casting and the process of deformation are presented in **Figure 3.** For the two remaining tested alloys a coarse-grained structure was observed (**Figure 3a**). After the process of plastic deformation grain refinement was observed in the microstructure of tested alloys. The biggest refinement was achieved for alloy WE43 (**Figure 3b**). Average grain diameter after deformation process was 0.908 μm [8].

LAE442(Mg-4%Li) | WE43

after casting a)

after hot plastic deformation b)

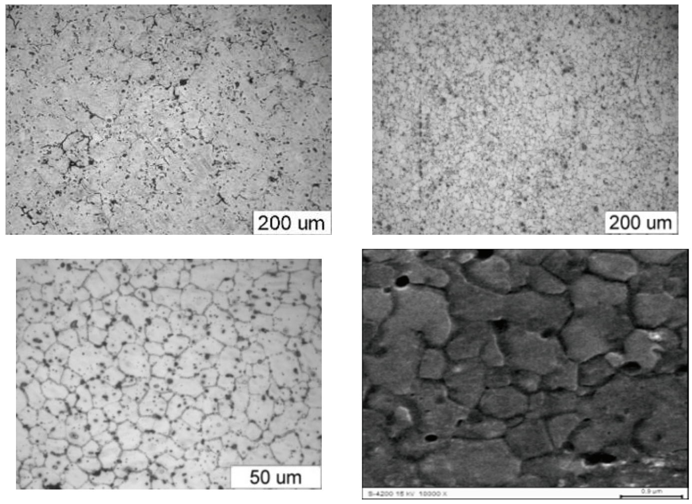


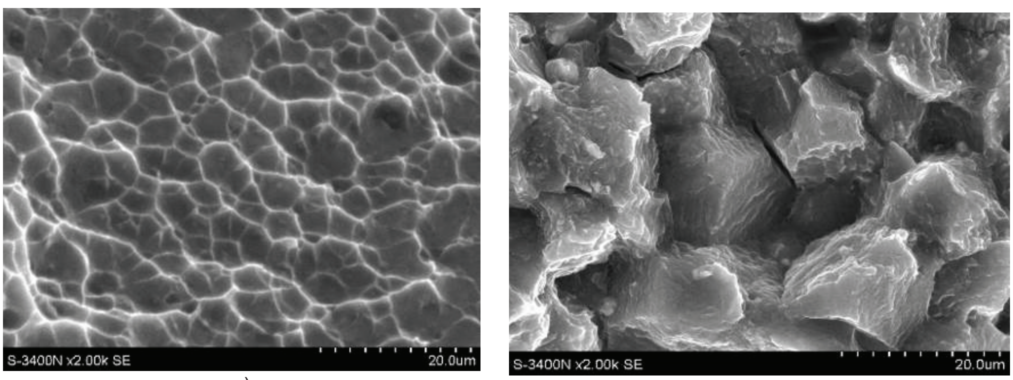
Figure 3 Microstructure of alloys: a) after casting, b) after hot plastic deformation

The tests of mechanical properties assessment for analysed flat bars were conducted on the resistance device ZWIK/Z100 in room temperature and in elevated temperature of 200°C. Results of mechanical properties after tension tests for alloys LAE442, WE43, determined in room and in elevated temperature (200°C), are shown in **table 2**.

Table 2 Results of tensile testing at the tested alloys at room temperature and increased 200°C

Alloys	Stress σ [MPa]	Elongation [%]	
		A room temperature	T=200°C
LAE442	221	20	22
WE43	269	24	25

Conducted tension tests allowed for marking the basic mechanical properties for tested alloys. For all tested alloys the plasticity is small in room temperature. Satisfactory results were achieved only for alloy WE43, LAE442 (Mg-4%Li). Temperature elevation to 200°C caused the increase of resistance properties. For alloy WE43 the achieved elongation was bigger by 25%. Samples after resistance tests underwent fractographic tests in order to determine the character of the fracture. Micro-photos of the chosen fractures in samples deformed in room temperature and elevated temperature are shown in **Figure 4.**



a) b)

Figure 4 Fractures surface after the tensile test at temperature: a) a room - WE43, b) increased to 200°C - LAE442 (Mg-4%Li)

For alloys after stretching in room temperature the ductile fracture is observed (**Figure 4a**). However, fractographic tests conducted for alloy LAE442 (Mg-4%Li) ruptured in temperature of 200ºC have shown the presence of mixed fractures with some ductile and brittle areas (**Figure 4b**). The results of hardness measurements for tested alloys are shown in **Figure 5**. Hardness measurements after the casting process of tested ingots have shown that the biggest hardness was found in alloy WE43. An increase of hardness was found in tested materials after extrusion process. Hardness increased for all the tested alloys in comparison with initial condition. The biggest increase of hardness after deformation process was observed in alloy WE43 (**Figure 5**).

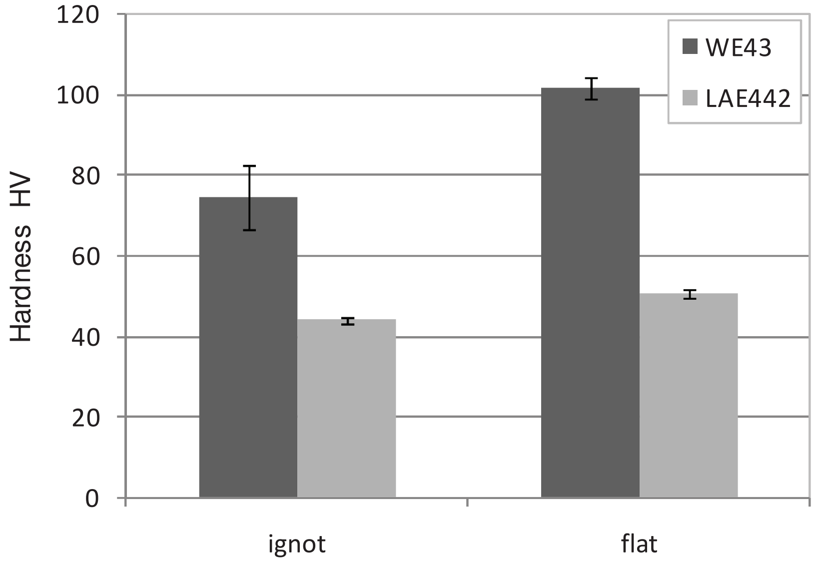


Figure 5 Hardness of the investigated alloys

4. CONCLUSIONS

Shaping flat bars with the use of cold extrusion in complex deformation condition has allowed for the achievement of grain refinement in the structure of tested alloys. For alloy WE43 after deformation process the mean diameter of grain was achieved which equals 0.908 μm. Conducted tests make it possible to achieve the basic mechanical characteristics. Results of the performed tension tests show that alloys WE43 and LAE442 allow for the achievement of the bigger resistance and better plastic properties in room temperature as well as in elevated temperature. Further tests will concentrate on getting to know the structural phenomena which occur in structure of tested alloys after plastic deformation with the use of methods of transmission and scanning-transmission microscopy.

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