THE MICROSTRUCTURE AND PROPERTIES OF MAGNESIUM ALLOYS Mg-Li-Ca AFTER THE PROCESS OF EXTRUSION

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Abstract

The article presents tests results of the influence of hot extrusion process on the microstructure and mechanical properties of alloy Mg-4Li-1Ca. Materials for tests were ingots which included in their chemical composition, apart from Mg and Li as the basic ingredients, such chemical elements as calcium in the amount of 1% mass. Alloy Mg-4Li-1Ca was achieved in the process of smelting in the shielding gas atmosphere (argon) and then casting into graphite moulds. Before the process of straining the ingots underwent homogenisation. An analysis was conducted of the microstructure in initial condition and in condition after plastic deformation with the use of techniques of light and scanning microscopy. The paper presents results of tests of mechanical properties marked in static compression tests in room temperature.

Keywords: Mg-Li-Ca alloys, microstructure, hot deformation, extrusion process

1. INTRODUCTION

At present, the aviation and car industries are becoming more and more interested in magnesium alloys, the application of which influences the reduction of weight of the means of transport. Manufacturing of semi-products and products from magnesium alloys is mainly based on technology of casting which results from good casting properties of those materials. Application of the processes of the plastic processing is restrained but, as a consequence, it provides better operating properties. Materials tests as well as tests of manufacturing processes of the semi-products from magnesium alloys which were plastically processed are currently in the phase of intensive development [1-3]. The Institute of Materials Science of the Silesian University of Technology conducts research works devoted to elaboration of shaping technology for magnesium alloys. Besides the conventional magnesium alloys such as AZ61, WE43 and AZ31 the attention was also turned to the new generation of the ultra-light alloys which include lithium in their chemical composition. It is assumed that 1% of lithium weight content in the magnesium alloy reduces its density by about 3%. Additionally, it reduces the resistance to corrosion, due to high reactivity of lithium [6], which results in the limitation for technical application of those alloys. Due to their phase composition connected with the lithium content, alloys Mg-Li can be divided into three main groups: mono-phase with structure α, two-phase α+β, and mono-phase with structure β [1,6]. Literature data connected with magnesium alloys with lithium show that conducted research was concentrated on the optimization of the chemical composition by introduction of the additional chemical elements such as: Al, Ca, RE (mischmetal) which improve the resistance of the alloy and its temperature stability; improvement of the vacuum smelting technology and casting technology [5] as well as the application of hot-plastic working in shaping structure and mechanical properties. Apart from those difficulties magnesium alloys Mg-Li which are plastically processed, beside the decrease of the weight of alloy also give the possibility of significant improvement on the deformability and implementation of shaping in room temperature. The tests which have been conducted so far on the conventional alloys and new ultra-light magnesium alloys type Mg-Li, the results of which are presented in papers [2-7], as well as literature data have become the premise to start research on this group of materials. Introduction of calcium to the chemical composition of Mg-Li alloys influences on the improvement of resistance to creep and resistance to corrosion in elevated temperature. It also has a beneficial influence on the microstructure which is fine-grained. Moreover, it is deoxidizing during casting and heat treatment. New, ultra-light Mg-Li-Ca alloys may become promising materials of the future, due to their low density, good resistance, ductility and bio-compatibility to be applied in medicine in biodegradable implants and surgical suture [8-9]. They can also become an alternative to the currently applied conventional magnesium alloys. The paper presents the results of tests which analyse the microstructure and properties of Mg-4Li-1Ca alloy in initial state and after extrusion process.

2. EXPERIMENTAL PROCEDURE

Materials for extrusion process were ingots with a height of 90mm and diameter of ϕ 40mm from magnesium alloy Mg-4Li-1Ca [% mass]. The alloy was smelted in single-compartment, laboratory induction vacuum furnace VSG 02 by Balzers company [5]. **Figure 1** shows an example primary structure and the appearance of the achieved ingot from magnesium alloy Mg-Li-Ca after casting process. Macrostructure of the achieved ingots consists only of equiaxial grains (**Figure 1b**). The lack of presence of areas with columnar grains - despite the fact of casting into graphite moulds which quickly absorb heat - indicates that the tested alloy has a strong tendency to volume crystallisation. It is a very beneficial phenomenon because the fine-grained, complex structure consisting of equiaxial grains usually has a better technological plasticity than the structures in which columnar grains dominate. There was a heat treatment conducted for tested alloy in temperature of 400°C, with annealing for 3h and cooling in furnace all performed after casting process.

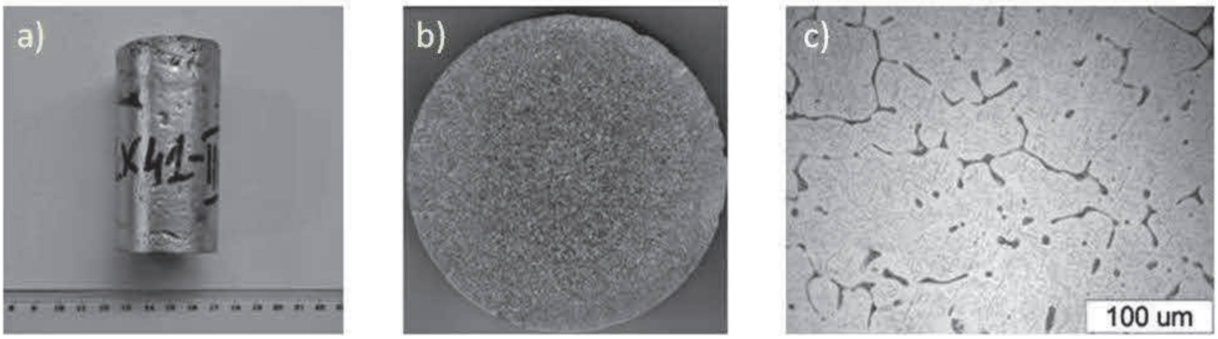


Figure 1 Alloy Mg-4Li-1Ca after casting process: a) the appearance of the ingot, b-c) macrostructure

After casting process and homogenisation the alloy Mg-Li-Ca underwent extrusion process. The process was conducted in the Institute of Metals Technology of Silesian University of Technology on hydraulic press with the use of hydraulic press Hydromet. The temperature applied for extrusion was 400ºC and capacity force of the press of 420 [kN]. The effect of conduction of extrusion process was achievement of rods with diameter of 10 mm. The surface of the achieved rods was correct and did not include any defects. The analysis of microstructure was conducted after each conducted stage of tests with the use of light and scanning microscopy techniques. Tests of mechanical properties of the achieved rods were conducted with the use of testing machine Zwick/Roell Z100, in room temperature. Measurements of micro-hardness were done with the use of Vickers method with load of 0.2kG (HV0,2) on samples in initial condition and after extrusion process.

3. RESULTS AND ITS DISCUSSION

Figure 2 presents example microstructure of alloy Mg-4Li-1Ca after casting and homogenisation. The homogenisation has been conducted in temperature of 400ºC for 3 hours. Samples were cooled in furnace. According to literature data [8] in alloy Mg-4Li-1Ca in condition after casting and homogenisation there are phases α-Mg, Li_2Ca and eutectics (α-Mg, Mg_2Ca) present. In the microstructure in the initial state there were traces of dendritic structure with clearly marked grain boundaries observed. There was also a eutectic found with lamellar structure situated in inter-dendritic areas of phase α-Mg (**Figure 2**). Authors of the paper [8] have shown that the eutectic is a mixture of phases α-Mg and Mg_2Ca. The conducted analysis of the chemical composition confirms the bigger concentration of Ca in the locations where the mentioned eutectic can be found (**Figure 3**). The content of lithium and its distribution in the alloy was not defined due to the limitations of the testing methodology.

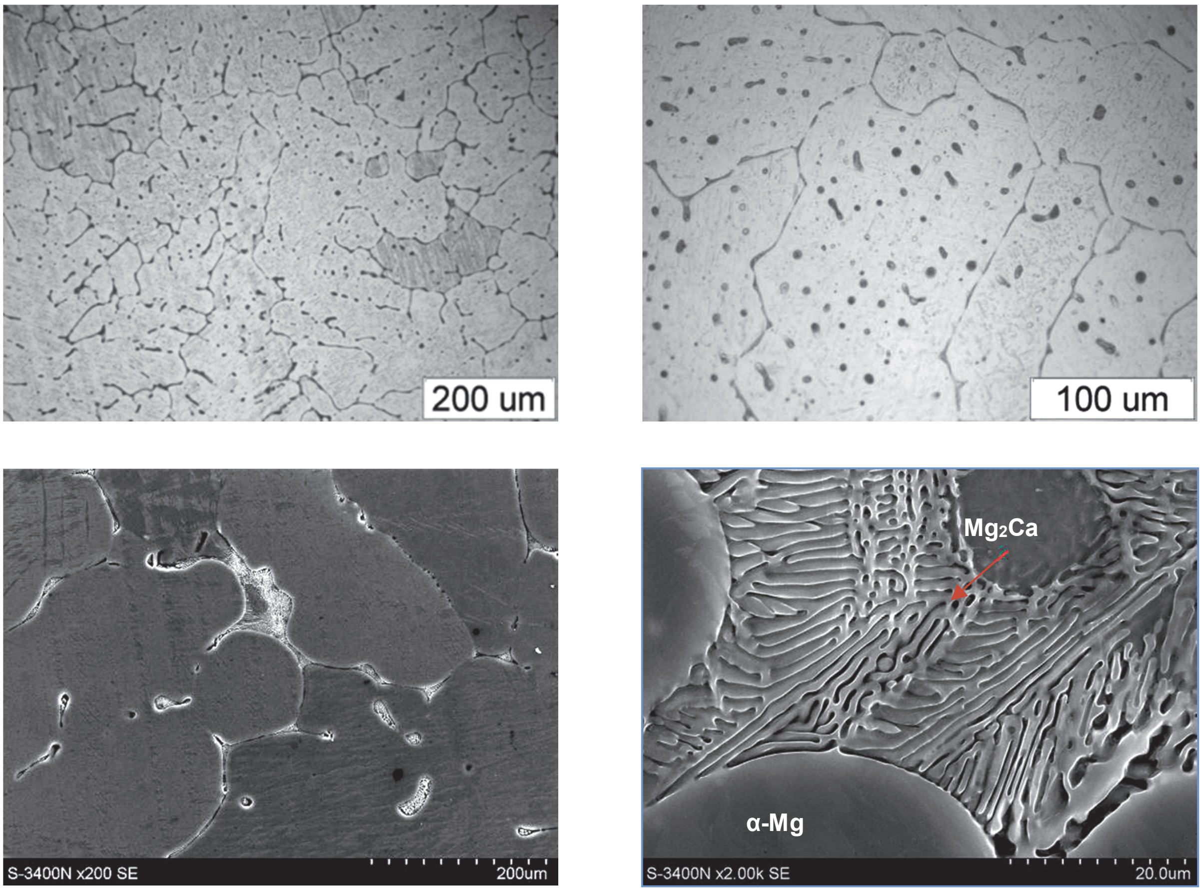


Figure 2 Microstructure of alloy Mg-4Li-1Ca after casting and homogenisation, visible eutectics with lamellar structure in inter- dendritic areas

Sample microstructures of alloy Mg-4Li-1Ca after extrusion process are presented in **Figure 4.** Microstructure of the tested alloy after extrusion process was characterised with the presence of equiaxial, recrystallised grains inside of which there were deformation twins. After extrusion process the observed eutectics are present mainly on grain boundaries and form a band arrangement. There were micro-hardness measurements HV0.2 conducted on samples in initial condition and after extrusion process. There were no significant differences found between the initial condition where the micro-hardness equalled 45 HV0.2 and after extrusion process where it was 47 HV0.2. Mechanical properties were marked in static compression tests in room temperature. Achieved results show the deformability of the tested alloy presented in the form of relative draft to cracking which equalled 312 [MPa]. Resistance to compression equalled 17%.

Figure 5 presents chosen microstructures after static compression test. In the microstructure of alloy Mg-4Li-1Ca after static compression test some grain growth was observed together with growth twins which are particularly in phase α-Mg.

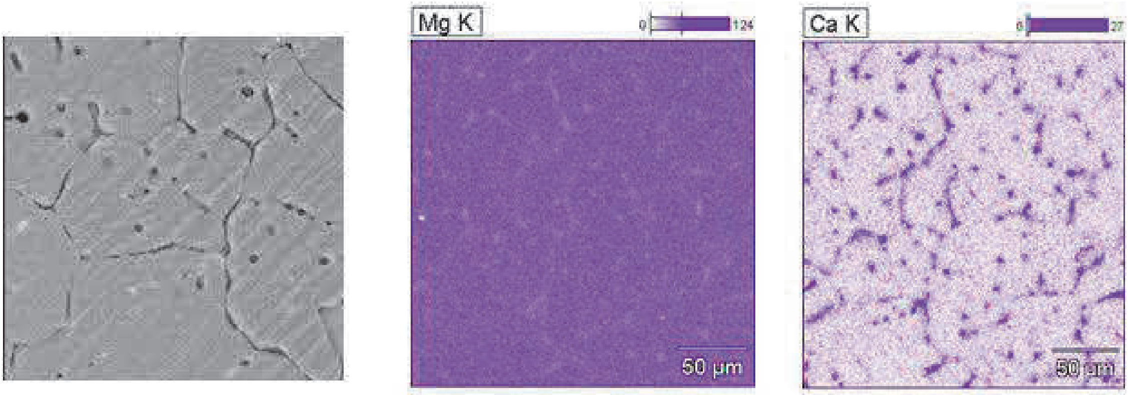
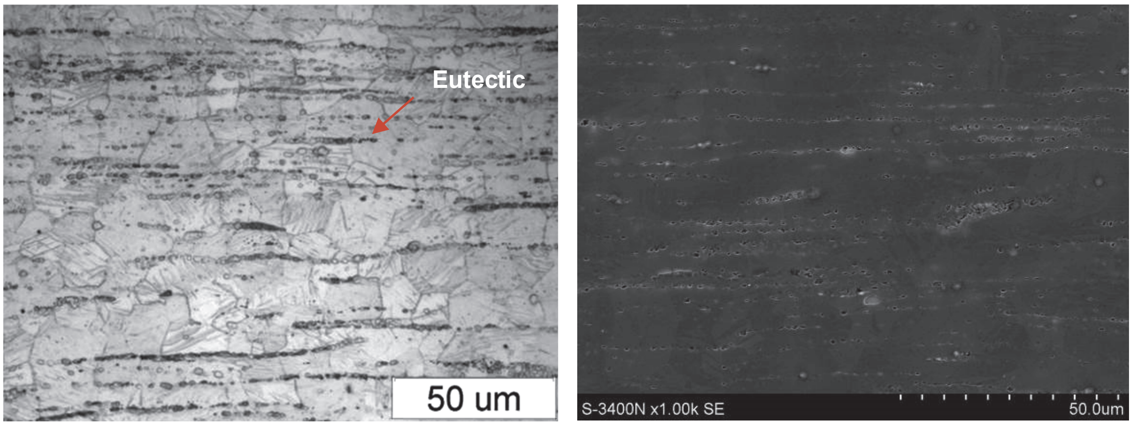


Figure 3 Surface distribution of elements Mg, Ca in alloy Mg-4Li-1Ca after processes of casting and homogenisation



LM SEM

Figure 4 Microstructure of alloy Mg-4Li-1Ca after process of extrusion

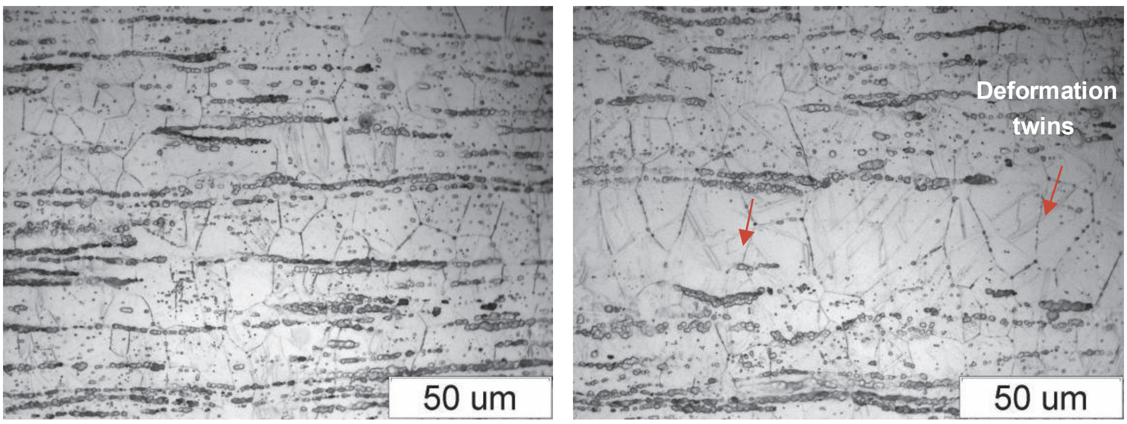


Figure 5 Microstructure of alloy Mg-4Li-1Ca after static compression tests in room temperature

4. CONCLUSION

Magnesium alloys with lithium are a new generation of ultra-light construction materials. Introduction of lithium to the chemical composition was aimed at the decrease in the density of the alloy and at the same time increase of their deformability. The introduction of calcium, however, works deoxidising during the processes of heat treatment and casting. It also influences beneficially on the resistance to corrosion and resistance to creep in elevated temperature. Conducted tests have shown that in initial state the microstructure of alloy Mg-4Li-1Ca is dendritic with the presence of eutectics located mainly in the inter-dendritic areas of phase α-Mg. After extrusion process and as a result of recrystallisation the fine-grained microstructure was achieved. The results of conducted compression tests in room temperature show that the tested alloy has beneficial resistance properties and plastic properties.

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