INFLUENCE OF HOT DEFORMATION ON MICROSTRUCTURE AND PLASTIC PROPERTIES OF Mg-Al-Zn-Mn TYPE ALLOY

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Abstract

The aim of the study was to evaluate the effect of deformation parameters on the plasticity and microstructure of alloy AZ31. Continuous, two-stage and multi-stage hot deformation tests were performed to analyze the effect of parameters such as heating temperature, deformation size, deformation speed and deformation time after deformation on the alloy microstructure and plasticity of the alloy. In addition, the activation energy and the fraction of weakness for the individual samples were determined.

Keywords: Magnesium alloys, microstructure, hot deformation, flow stress

1. INTRODUCTION

Magnesium and its alloys characterise with interesting properties such as: high proper resistance, good cast-ability and good weldability which all cause that they are the most attractive materials for application in aviation and automotive industries. Up to the present moment the application of the magnesium alloys has been limited to products which are achieved through casting methods which limits their application range. Thanks to plastic treatment the magnesium alloys can become an interesting alternative but the technology of plastic shaping is complicated due to their low plasticity in room temperature [1-3]. Alloys from group Mg-Al-Zn are the most common. In this group there are four basic kinds: AZ21, AZ31, AZ61 and AZ80. Alloys AZ21 and AZ31 possess average mechanical properties, they are weldable and can be easily rolled and extruded. These alloy types are used for preparing metal sheets which are meant for sheet metal stampings. Magnesium alloy AZ31 has alloy additives in the form of aluminium - 3 %, zinc - 1 % and manganese below 0.5 %. Alloy additives improve the strength of the alloy as well as the resistance to brittle cracking [4-6]. The hot working flow stress and structure for wrought magnesium alloy AZ31 have been analyzed [7, 8]. After extrusion and annealing, alloy specimens were subjected to axial-symmetric compression test on GLEEBLE thermo-mechanical simulator. In order to analyze the processes which take place during deformation, the specimens after deformation were intensely cooled with water. The processes of structural reconstruction, which take place during deformation, have been detected.

2. EXPERIMENTAL PROCEDURE

The article presents the hot working flow stress and structure for wrought magnesium alloy AZ31 have been analyzed. Test materials were rods from alloy AZ31 after extrusion process. Chemical composition and mechanical properties of alloy AZ31 are presented in **Table 1.**

Table 1 Chemical composition and mechanical properties of alloy AZ31

AZ31	Al	Zn	Mn	Si	Cu	Ca	Fe	Ni	Inne	Mg
	3.00	0.71	0.20	0.02	0.01	0.01	0.003	0.0001	0.30	balance
Mechanical properties	$R_{0,2}$ =150 MPa, R_m=230 MPa, A=8 %									

Axis-symmetric compression was performed using the Gleeble 3800 system. Samples of ø10 x 12 mm were placed in sintered carbide anvils. Large friction at the sample border-the surface of the anvil causes plastic flow to be heterogeneous. Lubricant was applied to minimize friction and graphite foil was placed between the sample and the anvil. Attempts were made in a protective atmosphere - vacuum + argon. Structural examination was carried out using light microscopy Axis-symmetric compression tests were conducted in temperature range from 250÷400 ºC at the rates of strain 0.01 and 1 s^{-1}.

3. RESULTS AND ITS DISCUSSION

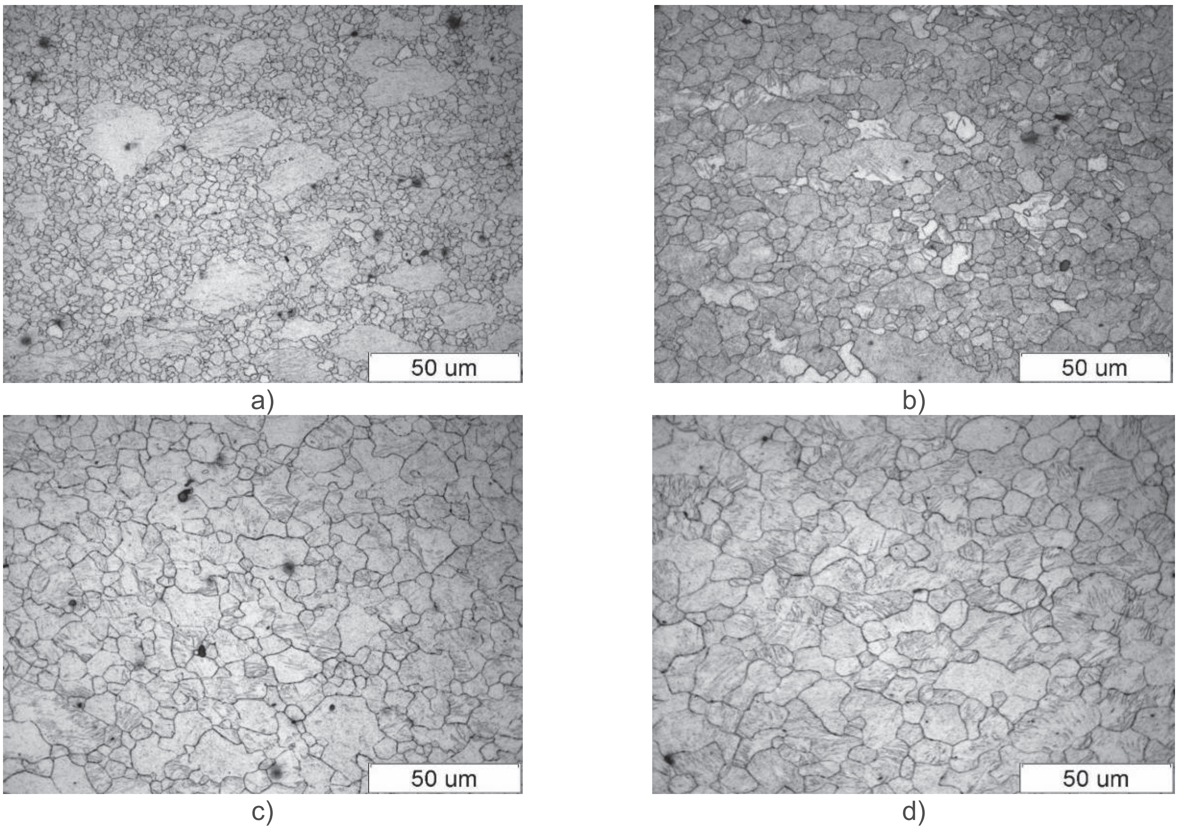

Figure 1 Comparison of the alloy microstructure after deformation at 250 °C a), 300 °C b), 350 °C c) and 400 °C d)

In the first stage, the influence of temperature, size and deformation rate on technological plasticity under continuous deformation was investigated. It was found that the increase of process temperature leads to intensification of recrystallisation processes (**Figure 1**) and recrystallisation grain growth (**Figure 1**). This is manifested by the decrease in the value of the plasticizing stress (**Figure 2**.). As the deformation rate increases, a fine microstructure is obtained, but not fully recrystallised. For the temperature of 250 ºC, after reaching maximum stress which equals 141 MPa and strain value of 0.2, a significant drop of yield stress occurs. It is connected with the undergoing process of recrystallisation. It is proved by the presence of small grains present on the primary grain boundaries (**Figure 1a)**. Elevation of strain temperature to 300 °C and 350 °C allows for the achievement of fully recrystallised structure(**Figures 2 b-c)**. Maximum stress is lower and reaches the value of 89 MPa for 300 °C and 65 MPa for 350 °C **(Figure 2)**. The last option of strain was strain in temperature of 400 °C where the yield stress was 45 MPa. The observed structure in this case is fully recrystallised (**Figure 1d)**. Double and multiple strains can be observed in many technological processes. A multi-pass hot rolling process can serve as a good example here. In case of rolling, the gap between the deformations is also important. Therefore, two-stage deformation experiments were conducted to determine the impact of the time between the deformations. The 1s between the deformations leads to further strengthening of the material. Increasing the hold time leads to a decrease in the strengthening level (**Figure 3)** In case of deformation with 30 s and 60 s, the curves actually overlap. Determined values of fractions of weakness, confirm that with the increase in holding time the number of recrystallised fractions increases (**Figure 4**). Rolling is also important in multi-step deformation. Each successive deformation causes the grain to be crushed, and in the time between the deformations the recrystallisation and recovery process take place there. Experiments simulating the conditions of such a process were conducted. The effect of temperature change on each successive deformation was studied. Simulated conditions of four-stage deformation were provided. Reducing the deformation temperature leads to the increase of the maximum stress (**Figure 5**), and the structure is less and less recrystallised. Analyzing the effect of the deformation rate and the durability time between the deformations, a 5-step deformation test was performed (**Figure 6**). The increase in speed resulted in the increase of the maximum stress and the structure was recrystallised to the smallest level. Lower speeds exhibited a higher degree of recrystallisation, which was reflected in the decrease in maximum stress. The analysis of the effect of the time between the successive deformations showed that the prolongation of the retention time leads to a decrease in the maximum stress. The difference in these values increases with each successive deformation (**Figure 7**).

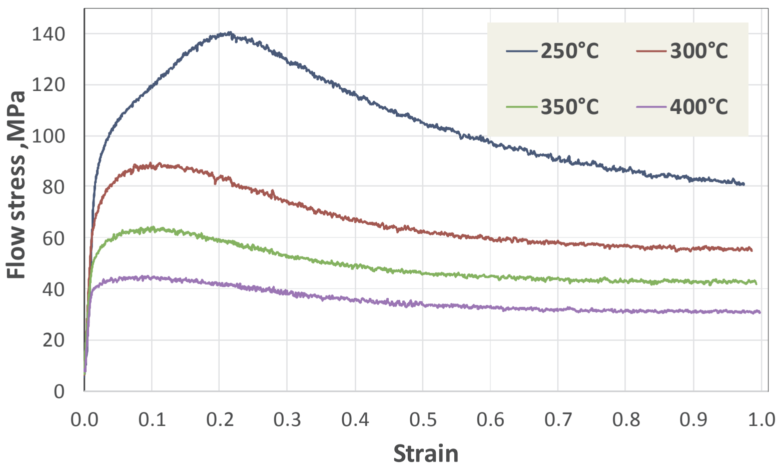

Figure 2 Flow curves with different deformation temperatures at constant deformation rate

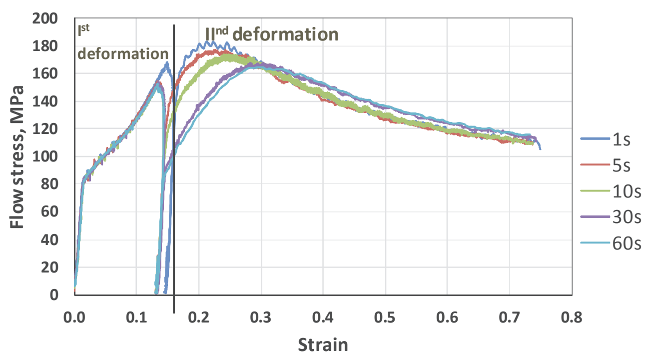

Figure 3 Flow curves obtained after two-stage deformation at different times of resistance before further deformation - 1 s, 5 s, 10 s, 30 s and 60 s

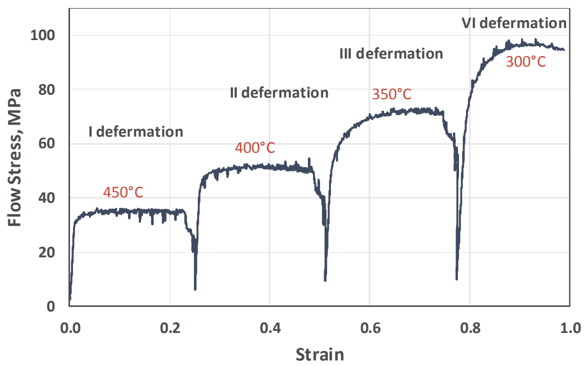

Figure 4 Flow curve obtained under four-stage deformation conditions

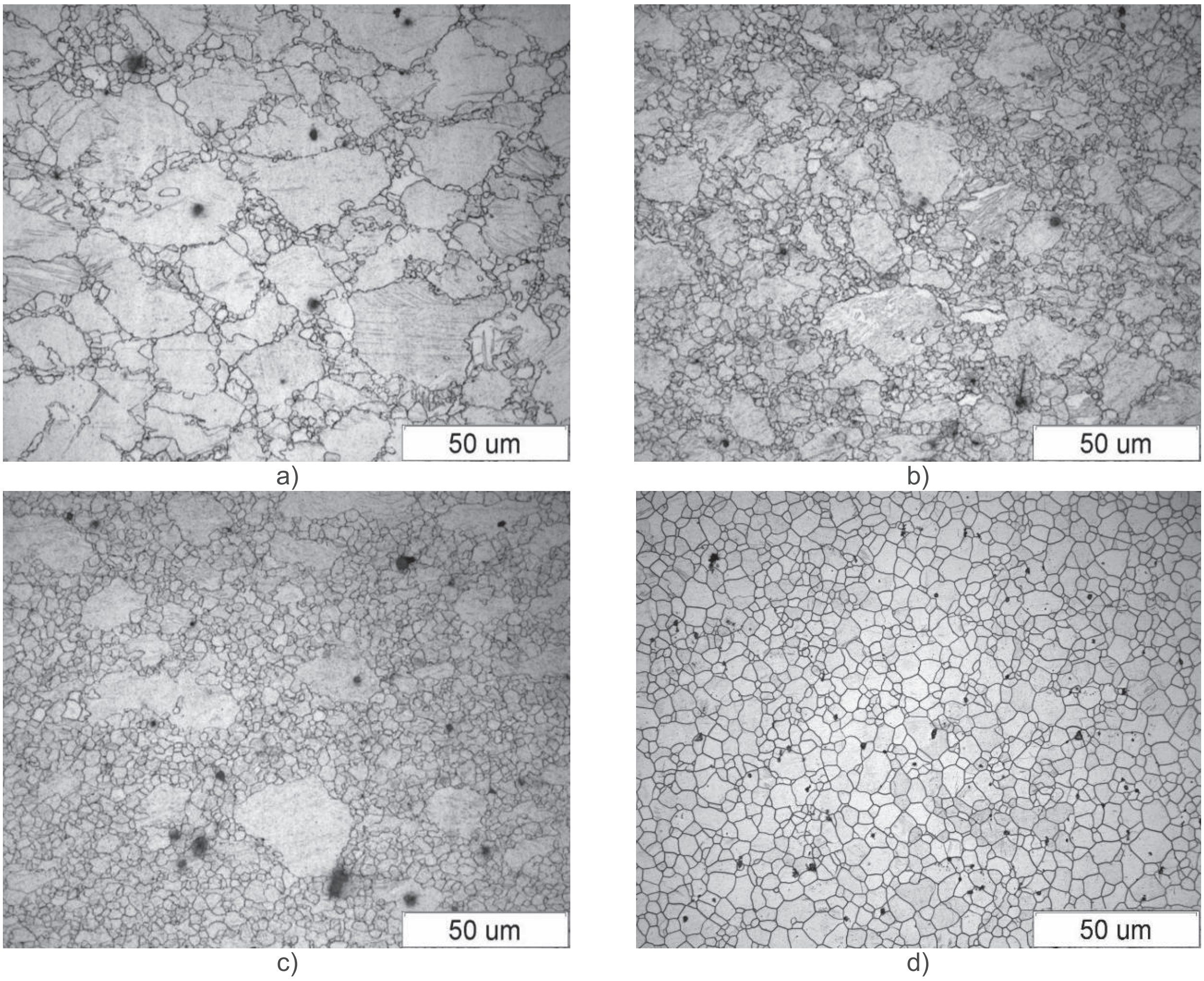

Figure 5 Microstructure of samples at different time of between deformations: a) 5 s, b) 10 s, c) 30 s and d) 60 s

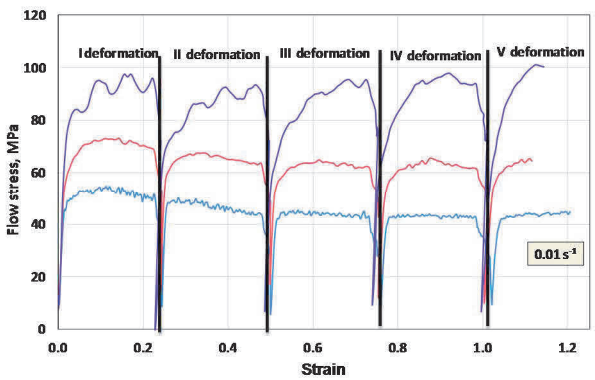

Figure 6 Flow curves obtained during the 5-step deformation at deformation rate

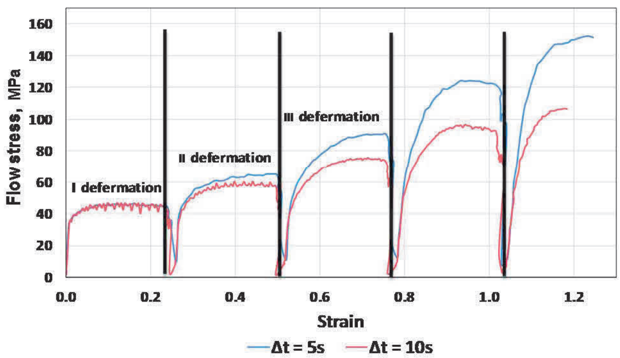

Figure 7 Flow curves obtained during the 5-step deformation with the time between the deformations Δt = 5s and Δt = 10s

CONCLUSION

Conducted tests allowed for determination of the behaviour of alloy AZ31 in conditions of process with various deformation parameters which are temperature, speed and size of strain as well as holding time between each following strain. Knowledge of those dependencies is particularly important in case of designing the technology of hot-working in industrial conditions for manufacturing products and semi-products from alloy AZ31. Microstructure of alloy AZ31 should be shaped in such a way so that in the process of working the smallest possible grain refining could be achieved. Such conditions allow for the preparation of products with required mechanical properties. It was proved here that the higher the temperature of strain, the bigger the part of the recrystallised grains in the structure and also the bigger the drop in the maximum stress. Time extension for holding between the stresses causes the increase in the degree of structure recrystallisation and the values of maximum stress in the second strain decrease. The work carried out in the study will be helpful in selecting the parameters of the plastic processing processes.

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