153 Creep Deformation Mechanisms of AZ31 Magnesium Alloys at Room Temperature by High Resolution Digital Image Correlation

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Abstract. Much effort has been made to improve the ductility of Mg alloys and lower their anisotropy by adding Al, Zn, and Mn alloying elements. Although these elements enhance their performance and die cast-ability, the application of Mg alloys as structural parts in industry is still limited. Besides the difficulties of corrosion and formability, creep is one of the most significant damage failure mechanisms of Mg alloys affecting their long-term behaviour. In this study, we develop a quantitative understanding to the creep mechanisms in an AZ31 Mg alloy at room temperature at the microstructural (grain) scale by High-Resolution Digital Image Correlation (HR DIC). Creep tests using HR DIC have been performed by a specific tensile rig which allows in-situ use at low strain rates and different range of temperatures in the Tescan S8000 SEM. In this way, creep deformation and strain accommodation mechanisms of the AZ31 Mg alloy at room temperature have been investigated at high resolution.

Introduction

Magnesium and magnesium alloys are considered as the next generation of structural materials in cases where weight reduction is critical. This includes applications across a wide range of industries, such as aerospace components, telecommunication and portable microelectronics due to their high specific strength, and lower density than conventional structural materials [1, 2]. Nevertheless, due to the limited number of available slip systems in the hexagonal close-packed (hcp) crystal structure at room temperature, Mg alloys generally show strong anisotropic crystallographic textures which result in low ductility and formability [3, 4]. Performance has been improved by alloying with Al, Zn and Mn. Here, we examine creep behaviour attracting considerable critical attention since it plays a crucial role in determining the service life of materials under stress and temperature depending on time. Hence, it is important to shed on light on the deformation mechanisms of room temperature creep of Mg alloys [1, 5]. General creep deformation mechanisms contributing creep at room and elevated temperature are mainly classified into two parts; dislocation creep, and diffusion creep. There is also another creep mechanism, which is called as grain boundary sliding (GBS), bringing about the accommodation of grains after these main creep mechanisms taking place. It is mainly assumed that GBS is a valuable creep mechanism at both room and elevated temperature and occurs not only during creep deformation but also superplasticity [6].

Microstructural factors such as grain size distribution and orientation, grain boundary character strongly influence creep [3]. It is possible to study these effects by creep straining in-situ within a scanning electron microscopy while back scattered electron diffraction can reveal the grain structure, but they provide only a qualitative picture of the deformation. Here, we use in situ High-Resolution Digital Image Correlation (HR DIC) to reveal different slip, GBS, twinning, and strain distribution which occur during creep deformation of an AZ31 Mg alloy at room temperature at low strain rates.

Experiment

In this study, deformation mechanisms of an AZ31 (Mg–3Al–1Zn–0.3Mn %wt) Magnesium alloy (Fig. 1) under low constant strain rate have been investigated via in situ High-Resolution Digital Image Correlation (HR DIC) at room temperature. Specific tensile test specimens (Fig. 2a) were electro-discharge machined and prepared by mechanical polishing. Creep tests were performed by the Newtec MT1000 tensile rig which allows us to carry out in-situ creep tests at low strain rates and different range of temperatures under the Tescan S8000 microscope at two different strain rates, $5x10^{-5}$ s^{-1} and $5x10^{-6}$ s^{-1}, respectively. Each sample was initially prepared by mechanical polishing (Fig. 2a), and then scanned by EBSD (Fig. 2b) to reveal the grain structure and grain orientations before the creep tests. Then, the surfaces of each sample were prepared for HR DIC.

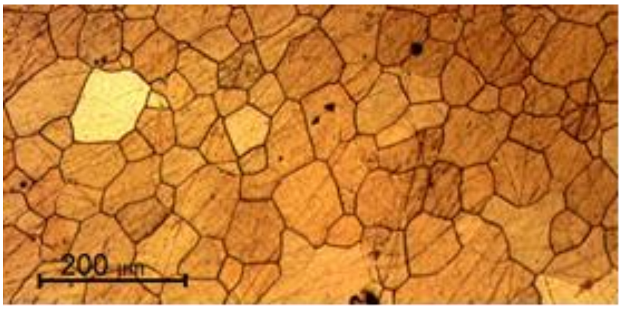

Figure 1 An optical microscope image of the AZ31 Mg alloy after etching

Results

Creep tests have been carried out in situ within the Tescan S8000 SEM based at different strain rates at room temperature (Fig. 2d). After the tests, these samples will be investigated through EBSD (Fig. 2e). This has provided us with a new picture of the deformation mechanisms of the AZ31 Mg alloy. It has been revealed the relationship between the extent of slip, the slip mechanisms and the underlying grain structure. In this way, the deformation mechanisms in quantitative and microscale level have been examined (Fig. 2f).

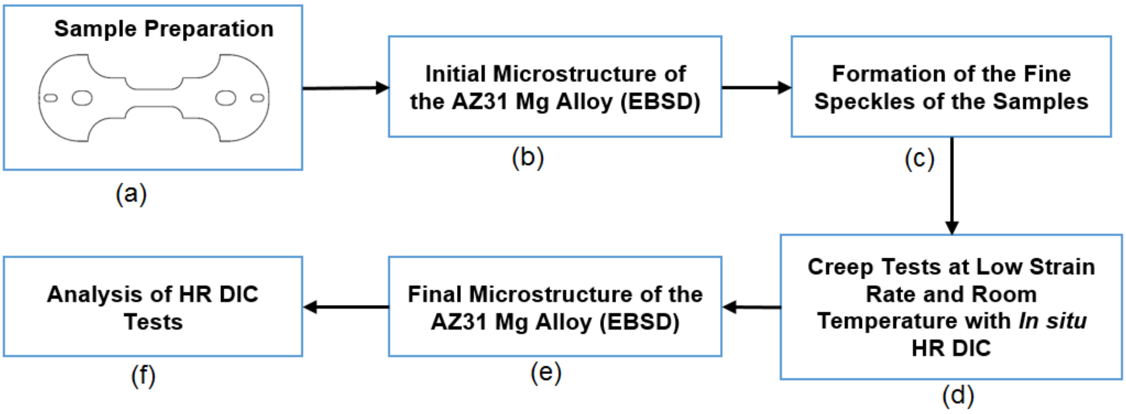

Figure 2 A schematic representation of the experimental procedure of in situ HR DIC during creep deformation of the AZ31 Mg alloy at room temperature.

Conclusion

We have provided insights into understanding the creep deformation mechanism of an AZ31 Mg alloy. The deformation mechanisms of the AZ31 Mg alloy such as dislocation slip, grain boundary sliding, and twinning have been observed under creep in quantitative and microscale level. In particular, this paper helps us to understand what contributes to creep deformation under constant strain rate, and how the intergranular and intragranular strain are accommodated at the microstructural scale through novel in situ HR DIC tests.

References

1. T. Matsunaga, T. Kameyama, K. Takahashi, and E. Sato: *Intragranular Deformation Mechanisms During Ambient-Temperature Creep In Hexagonal Close-Packed Metals,* Materials Transactions, 50 (12) (2009), p. 2865-2872.
2. P.S. Roodposhti, A. Sarkar, K. L. Murty, H. Brody, and R. Scattergood: *Grain Boundary Sliding Mechanism During High Temperature Deformation Of AZ31 Magnesium Alloy,* Materials Science and Engineering: A,, 669 (2016), p. 171-177.
3. S. K. Mishra, S. M. Tiwari, J. T. Carter, and A. Tewari: *Texture Evolution During Annealing Of AZ31 Mg Alloy Rolled Sheet And Its Effect On Ductility,* Materials Science and Engineering: A, 599 (2014): p. 1-8.
4. X. Chen, L. Wang, R. Xiao, X. Zhong, G. Huang, and Q. Liu: *Comparison Of Annealing On Microstructure And Anisotropy Of Magnesium Alloy AZ31 Sheets Processed By Three Different Routes,* Journal of Alloys and Compounds, 604 (2014): p. 112-116.
5. A. Orozco-Caballero, D. Lunt, J. D. Robson, and J. Q. Fonseca: *How Magnesium Accommodates Local Deformation Incompatibility: A High-Resolution Digital Image Correlation Study,* Acta Materialia, 133 (2017): p. 367-379.
6. T. G. Langdon: *An Analysis Of Flow Mechanisms In High Temperature Creep and Superplasticity.* Materials Transactions, 46 (9) (2005): p. 1951-1956.