Materials Chemistry and Physics 191 (2017) 99–105

Contents lists available at ScienceDirect

Materials Chemistry and Physics

journal homepage: www.elsevier.com/locate/matchemphys

EBSD analysis on restoration mechanism of as-extruded AA2099 Al-Li alloy after various thermomechanical processes

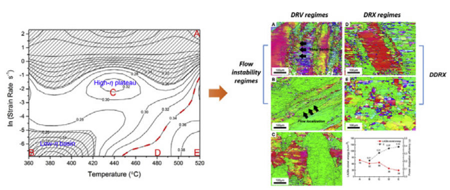
Xusheng Yang [a, b], Linjiang Chai [b, *], Weijiu Huang [a, b, **], Yanlong Ma [b], Zhenhao Zhang [b]

[a] College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China
[b] College of Materials Science and Engineering, Chongqing University of Technology, Chongqing 400054, China

HIGHLIGHTS

- Processing map is established for an as-extruded AA2099 Al-Li alloy.
- Stored energy calculation is performed to discriminate restoration mechanisms.
- DDRX is confirmed to occur in specimens with low Zenner-Holloman parameters.
- Power dissipation efficiency is demonstrated to relate to the restoration mechanisms.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 24 May 2016
Received in revised form
19 December 2016
Accepted 14 January 2017
Available online 17 January 2017

Keywords:
Al-Li alloys
Processing map
Restoration mechanism
Stored energy
Electron backscatter diffraction

ABSTRACT

Cylindrical specimens of as-extruded AA2099 Al-Li alloy are uniaxially compressed at temperatures ranging from 360 °C to 520 °C and strain rates ranging from 0.001 s^{-1} to 10 s^{-1}. Processing map of these specimens was established. Electron backscatter diffraction (EBSD) measurements were performed for specimens deformed under various conditions to probe their microstructures and restoration mechanisms. Stored energies in various specimens are calculated based on statistics of low angle boundaries via EBSD data. The remarkable decrement of stored energy and misorientation characteristics reveal that dynamic recrystallization (DRX) happens at 480–520 °C and 0.001–0.1 s^{-1}. Obvious DRX nucleation further suggests that this process should be classified to discontinuous dynamic recrystallization (DDRX). Stored energies in various specimens strongly affect the extents of dynamic recovery and dynamic recrystallization. By systemically considering the processing map and restoration behaviours of the specimens, the dynamic recrystallization regimes and the central high-η regimes are determined to correspond to preferable thermo-mechanical processing parameters for the as-extruded AA2099 Al-Li alloy.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

AA2099, which can be classified as the third generation of Al-Li alloys has been widely used in aerospace manufacturing owing to its higher specific strength and stiffness than conventional Al alloys [1]. The considerable potential for broad application of the AA2099 alloy requires its workability under various processing conditions and related restoration mechanisms to be well understood. In this

* Corresponding author.
** Corresponding author. College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China.
E-mail addresses: chailinjiang@cqut.edu.cn (L. Chai), huangweijiu@cqut.edu.cn (W. Huang).

http://dx.doi.org/10.1016/j.matchemphys.2017.01.044
0254-0584/© 2017 Elsevier B.V. All rights reserved.

respect, the processing map theorized first by Prasad et al. [2] on the basis of the dynamic materials model (DMM), has been demonstrated to be a powerful tool for many metallic materials. This theory suggests that the total power (P) absorbed by the work piece is the sum of power dissipation content (G) and power dissipation co-content (J) at any given temperature and strain rate. The content G means the power dissipated by plastic work, the majority of which is converted to heat. Although the remaining part of the energy stored in lattice defects is very small, this part of energy can considerably affect the restoration mechanism [3,4].

There have indeed been several efforts to analyze the processing map of Al-Li alloys [1,5–10], with related restoration mechanisms tentatively discussed. For example, previous studies suggested that dynamic recrystallization (DRX) could occur at a critical strain of compression, indicated by a gradual loss of flow stress after the peak value in stress-strain curves and a few small grains at triple junctions. However, optical microscopes often employed in the earlier work are not capable of quantitatively revealing grain boundary misorientation characteristics, thus not allowing the restoration mechanism to be reliably confirmed. Moreover, J. Liu et al. [11] insist that there is no evidence of dynamic recrystallization at the stress maximum in a superplastic forming process of 7050 suggesting that the gradual loss of flow stress may not relate to dynamic recrystallization.

Owing to such reasons, further studies on the calculation of energies stored in microstructure and the characterization of misorientation characters to confirm the restoration mechanism should be carried out. In this work, electron backscatter diffraction (EBSD) technique was mainly employed to investigate micro-textures and misorientation distribution characteristics of AA2099 specimens with different processing variables. Detailed analyses and discussions were then made to clarify the restoration mechanism, which is believed to facilitate assessment of its workability.

2. Experimental

A hot-extruded AA2099 alloy bar (extruded with an extrusion rate of 10 mm/s at 440 °C) was used as the initial material with its chemical composition (wt. %) listed in Table 1. Cylindrical specimens with dimensions of $\varnothing 10 \times 15$ mm^3 were cut from this extrusion bar. Isothermal compression tests were conducted by a Gleeble-3800 thermal-mechanical simulator, with the compression direction parallel to the prior extrusion direction (ED). The specimens were deformed at temperatures ranging from 360 °C to 520 °C at an interval of 40 °C and at strain rates ranging from 0.001s^{-1} to 10s^{-1}. All these specimens were heated from ambient temperature to these specific deformation temperatures at a heating rate of 10 °C/s and were maintained for 30s to secure a stable and uniform temperature before each test. During the compression, graphite was used to reduce friction between the specimens and crossheads. All these specimens were compressed by a reduction of 60% (true strain of 0.9) and water-quenched to ambient temperature to preserve the hot-deformed microstructures.

The compressed specimens were halved along their center axes. Before the EBSD examination, surfaces of the section planes were mechanically polished and then electrochemically polished in a solution containing 10 mL $HClO_4$ and 90 mL ethanol at 20 V and −25 °C for 90 s. All EBSD data were acquired from the center of the as-polished surfaces by a field-emission gun electron scanning electron microscopy (Zeiss Sigma HD). EBSD data for the initial specimen were acquired using a step size of 2 μm from an area of 1088 μm × 816 μm while that for each deformed specimen was acquired using a step size of 1.5 μm from an area of 571.5 μm × 429 μm.

Table 1
Chemical composition (wt%) of AA2099 alloy.

Li	Cu	Mg	Zn	Mn	Zr	Al
1.80	2.78	0.30	0.65	0.36	0.09	Bal.

3. Results

3.1. Initial specimen

The inverse pole figure (IPF) map of the as-extruded specimen (shown in Fig. 1a) reveals strip-like grains along the ED. Widths of these strip-like grains are about 150 μm. A major <111> fiber texture (<111>//ED) and a minor <001> fiber texture (<001>//ED) are found, the combination of which is a typical feature for Al extrusions [12,13]. Its band contrast (BC) map is shown in Fig. 1b. The poor BC indicates that the initial material is in a deformed state without annealing. As can be seen from Fig. 1c, the misorientation angle distribution (MAD) histogram is a bimodal one with a fraction of low angle grain boundaries (LAGBs, $2° < \theta < 15°$) as high as 73.5%.

3.2. Flow stress curves

The flow stress curves of the as-extruded AA2099 alloy deformed under different conditions are shown in Fig. 2. For all these curves, the flow stress generally exhibits a rapid increase, resulting from work hardening at the initial stage of the compression, and then it increases slowly to the peak value due to the dynamic restoration processes, i.e. dynamic recovery (DRV) or DRX [14–16]. After reaching the maximum value, the flow stress curves exhibit a steady state because of the equilibrium of work hardening and dynamic restoration process. During the compression, numerous dislocations can be generated, then piled up and tangled. Simultaneously, dynamic restoration processes begin at a critical strain, leading to flow softening.

It is known that the flow stress behavior could be considerably affected by the deformation condition. Both the peak value and the steady state value of the flow stresses of all these specimens increase with the increasing Zener-Holloman parameter (Z). Most of these flow curves exhibit a typical DRV-like shape, namely the flow stress increasing rapidly to the maximum value and then exhibiting a steady flow stage with no obvious peaks. The exceptional ones are specimens deformed at 10s^{-1} (Fig. 2a) and specimens deformed under low Z condition (Fig. 2e), for which the flow stress curves were DRX-like shaped [14,17]. However, it is well known that Al alloy is typically of high stacking fault energy, which usually allows deformed microstructures to be restored by a strong recovery rather than recrystallization. We thus postulate that the shape of the flow stress curve obtained at 10s^{-1} (with high Z) may not be caused by DRX. In fact, analyses on microstructures of these specimens, as to be presented in the following, support this view point.

3.3. Processing map

The processing map is in fact an instability map superimposed on a power dissipation map. The power dissipation map is a contour map of a non-dimensional efficiency index η, which can be expressed as [2].

$$\eta = \frac{J}{J_{max}} = \frac{2m}{m+1} \tag{1}$$

where m is the strain rate sensitivity of materials.

Download English Version:

https://daneshyari.com/en/article/5447867

Download Persian Version:

https://daneshyari.com/article/5447867

Daneshyari.com