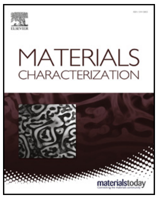
Materials Characterization 142 (2018) 352–364

Contents lists available at ScienceDirect

Materials Characterization

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



# Asymmetric cross rolling (ACR): A novel technique for enhancement of Goss/Brass texture ratio in Al-Cu-Mg alloy

Fatemeh Goli, Roohollah Jamaati*

*Department of Materials Engineering, Babol Noshirvani University of Technology, Shariati Ave., Babol 47148–71167, Iran*

ARTICLE INFO

*Keywords:*
Aluminum alloys
Crystallographic texture
Asymmetric cross rolling (ACR) process

ABSTRACT

The present work focused on the effect of asymmetric cross rolling (ACR) process as a novel technique on microstructure and texture evolution of Al-Cu-Mg alloys. The microstructural observation and bulk texture from RD–TD plane of the initial and deformed samples were characterized by optical microscopy (OM) and X-ray diffraction (XRD). It was found that the deformed Al-Cu-Mg alloy consisted of strong Goss, Rotated Goss, Goss-Brass, and $\alpha$-fiber textures. Usually, straight rolling leads to a significant strengthening of the Brass component with increasing strain in the Al-Cu-Mg alloy, but for asymmetrically cross rolled samples, the Goss orientation was stable after 40% deformation. Results showed that the ACR process was effective to intensify (up to 1.51 after 30% thickness reduction) the low Goss/Brass texture ratio often existing in the rolled Al-Cu-Mg alloy. During 30% ACR, the dynamic recrystallization (DRX) occurred, which led to increasing the intensity of Goss and Cube components and the fraction of extra high angle grain boundaries (EHAGBs).

## 1. Introduction

Al-Cu-Mg alloy is extensively used to manufacture aircraft skin sheets due to its fatigue crack propagation resistance and moderate strength [1, 2]. It is reported that the strength and fatigue performance dramatically affected by grain size [3, 4]. In general, grain refinement leads to higher strength and fatigue resistance owing to increasing the grain boundaries as barriers to dislocation movement and nucleation and growth of fatigue cracks [3–6]. However, fine grain size was not always associated with better fatigue performance [3, 4, 7, 8]. Some researchers revealed that short fatigue cracks failed to propagate through Goss $\{011\}\langle100\rangle$ grains but could easily pass through Brass $\{011\}\langle211\rangle$ grains [4, 9]. The Goss grains had a great twist component boundary or tilt angle component boundary with the neighboring grains, thereby retarding fatigue crack propagation, but the Brass grains exhibited a small resistance to fatigue crack propagation [10, 11]. Therefore, increasing the Goss/Brass texture ratio favors the improvement in fatigue resistance.

As is known, deformation texture of aluminum alloys during rolling process tend to eventually develop into a strong $\beta$-fiber running through the orientation space from the Copper $\{112\}\langle111\rangle$ component over the S $\{123\}\langle634\rangle$ orientation to the Brass $\{011\}\langle211\rangle$ component [12–15]. However, it was found that the conventional rolling deformation leads to create a strong Brass orientation and thus a very low Goss/Brass texture ratio in the Al-Cu-Mg alloys [2]. Therefore, it is a great challenge to achieve the high Goss/Brass texture ratio in this alloys.

The evolution of texture during rolling process strongly influenced by a change in strain path via cross rolling [16–26] and also asymmetric rolling [27–32]. Bhattacharjee et al. [19] investigated the effect of a change in strain path during cold rolling on the evolution of microstructure and texture in Al and Al-2.5%Mg. A pure metal or Copper-type texture observed in unidirectional cold rolled materials, while cross cold rolling led to the significant strengthening of the Brass component. Liu et al. [20] studied the influence of cross rolling on the recrystallization texture of a continuous cast Al-Mg alloy. They reported that the cross rolled sheet appears to be a continuous recrystallization texture transition from the Cube component through the $\{407\}\langle734\rangle$ orientation to the R component when the cross rolling reduction increases from 0% to 91%. Jin and Lloyd [31] investigated the reduction of planar anisotropy by texture modification through asymmetric rolling and annealing in AA5754. After unidirectional asymmetric rolling, the deformation texture was rotated by around 10° about the transverse direction from the FCC plane strain compression texture ($\beta$-fiber texture), whereas it was close to the ideal $\beta$-fiber texture after reverse asymmetric rolling. Kang et al. [32] studied the effect of asymmetric rolling on the texture and mechanical properties of the AA6111 alloy. They reported that the asymmetrically rolled sample contains a relatively higher fraction of shear textures than the conventionally rolled sample. Among these shear textures, the Rotated

---

* Corresponding author.
*E-mail address:* jamaati@nit.ac.ir (R. Jamaati).

https://doi.org/10.1016/j.matchar.2018.06.004
Received 8 March 2018; Received in revised form 25 May 2018; Accepted 3 June 2018
Available online 04 June 2018
1044-5803/ © 2018 Elsevier Inc. All rights reserved.

**Table 1**
The chemical composition of Al-Cu-Mg alloy (in wt%).

| Cu | Mg | Mn | Fe | Si | Zn | Al |
|---|---|---|---|---|---|---|
| 4.4 | 1.5 | 0.50 | 0.39 | 0.08 | 0.04 | Bal. |

Cube {001}〈110〉 orientation is stable during recrystallization, which affects the subsequent mechanical properties of the alloy sheets. Recently, in our previous studies [33] it has been shown that it is feasible to intensify the Goss/Brass texture ratio for improving the fatigue resistance in the AA2024 aluminum alloy by means of asymmetric cold rolling. This process resulted in increasing the Goss/Brass texture ratio to 1.32 after 40% reduction in thickness.

Owing to the aforementioned background, several studies have been reported on the use of the asymmetric rolling or cross rolling to control the crystallographic texture. Surprisingly, there are no studies focusing on the evolution of texture during asymmetric cross rolling (ACR) of aluminum alloys. Therefore, the main purpose of this work is to investigate the microstructure and texture development in the Al-Cu-Mg alloy under asymmetric cross rolling, and its effect on Goss/Brass texture ratio. The aim of the present study is to identify whether the ACR process has sound effects to improve the low Goss/Brass texture ratio usually found in rolled Al-Cu-Mg alloy.

## 2. Experimental Procedure

AA2024–T3 aluminum alloy plate with an initial thickness of 10 mm was used as starting material. The chemical composition of the AA2024 alloy is given in Table 1. The plate was initially annealed at 500 °C for 1 h. The rolling experiments were performed at ambient temperature using a laboratory rolling mill with a roll diameter of 150 mm. The method used in the present work for the asymmetric rolling was single roll drive and the rotational speed of the lower roll was fixed at 50 rpm. The total reductions were 10%, 20%, 30%, and 40%. Let RD, TD, and ND represent the rolling direction, transverse direction, and normal direction, respectively. The samples were rotated around the ND 90° between the consecutive passes so that the RD and TD were mutually interchanged in each 10% thickness reduction. Schematic illustration of the ACR process is shown in Fig. 1.

The microstructure of samples was observed by optical microscopy on the RD–TD plane. Standard metallographic sample preparation techniques were used with two etchants based on Keller's and Kroll's reagents. Macrotexture measurements were performed by X-ray diffraction (XRD) on the RD–TD plane. The texture was measured at the quarter-thickness of the AA2024 plate. Rectangular samples along the rolling direction (RD) were used with dimensions of $10 \times 15\,\text{mm}^2$ (width × length). The XRD system used was an Xpert Pro (PANalytical) with Cu Kα radiation operated. The orientation distribution functions (ODFs) were calculated from incomplete {111} and {200} pole figures (PFs) using the TexTools software (ResMat Co.). Then, the {111}

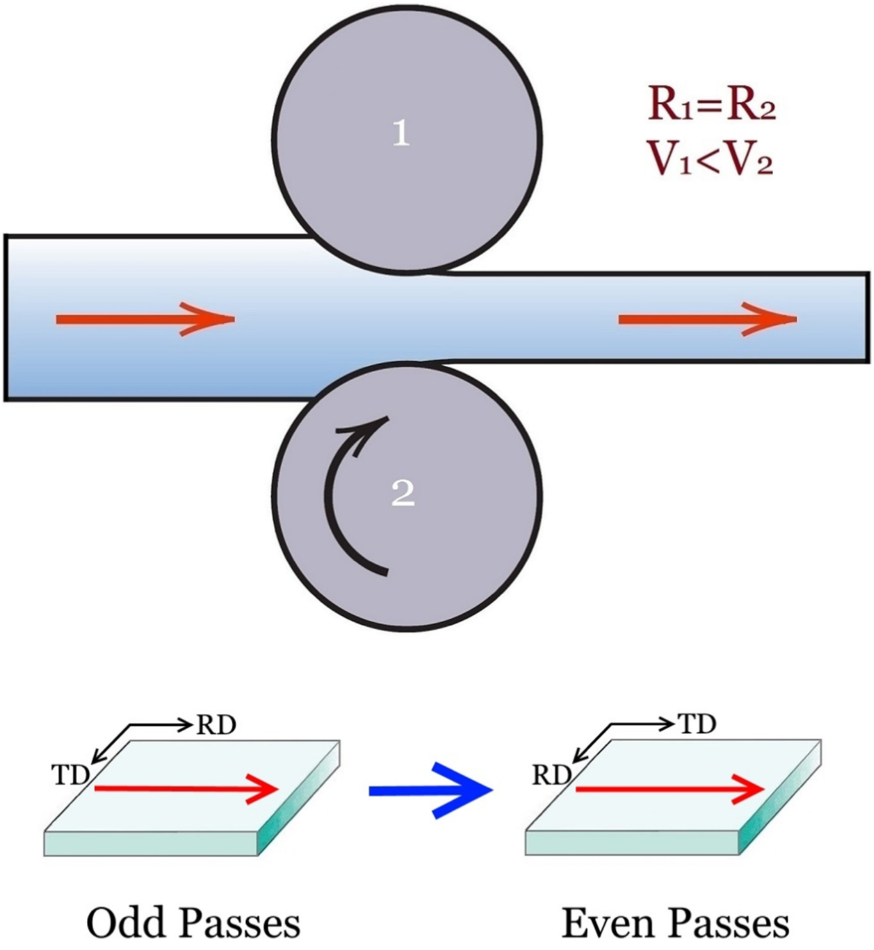


**Fig. 1.** Schematic illustration of the ACR process.

Download English Version:

https://daneshyari.com/en/article/7969068

Download Persian Version:

https://daneshyari.com/article/7969068

Daneshyari.com