Materials Science & Engineering A 733 (2018) 307–315

Contents lists available at ScienceDirect

Materials Science & Engineering A

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

Effect of deformation routes on the microstructures and mechanical properties of the asymmetrical rolled 7050 Aluminum alloy plates

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ARTICLE INFO

Keywords:
Asymmetric rolling
Deformation routes
7050 Al alloy
Microstructures
Mechanical properties

ABSTRACT

Asymmetric rolling (ASR) with three different deformation routes and conventional symmetric rolling (CR) were carried out in 7050 Al alloy plates, so as to study the influence of deformation route on the strain distribution, microstructural evolution and mechanical properties. The results show that the ASR process introduces much more effective strain throughout the thickness, resulting in severe deformation or microstructural evolution and improving the alloy's ductility compared to CR deformed samples, irrespective of the deformation routes. Among the three ASR deformation routes, the ASR-R process can introduce highest strains to improve the through-thickness deformation homogeneity, subsequently amount of finer subgrains can be observed in the wider shear band zones due to the intersection of shearing patterns of adjacent rolling passes. Although the strengths of the ASR-processed plates are almost similar, their tensile elongations are obviously affected by the deformation routes, especially the ASR–R route contributes to ~ 23% elongation, which would be mainly responsible by the grain refinement, homogeneous distribution of microstructure and fragmentation of coarse constituent particles.

1. Introduction

As the most important structural lightweight material, large-scaled 7000 series Al alloy plates with excellent strength–to–weight ratio and good corrosion resistance have been widely used in aerospace industry. The plates are generally processed by conventional symmetric rolling (CR) [1,2]. The compressive deformation plays the key role and shear deformation is only concentrated on the surface due to the friction between the workpiece and rolls for CR deformed plate, which leading to distribution inhomogeneity of microstructure throughout the thickness. As a result, there is measurable reduction in the final mechanical properties and its throughout-thickness homogeneity [3].

Asymmetric rolling (ASR) is a process with different rotation speeds for upper and lower rolls [4,5]. This process introduces much more shear deformation and produces through-thickness uniform plastic strain. The influences of ASR on the microstructure and mechanical properties of Al alloys have been recently investigated. The additional shear deformation induced by ASR into the center of the rolled sheets or plates can serve as an effective path to modify the through–thickness homogeneity of microstructures and mechanical properties [6–8]. Also, the additional shear deformation can play a critical role in grain refinement for the ASR–processed materials [9,10]. Therefore, the introduction of much more additional shear deformation into the rolled plates would be considered as a useful way to improve the through-out–thickness deformation homogeneity. It has been found that the magnitude of shear deformation increases significantly with increasing the speed ratio (SR) [7,9–11], and the mechanical properties of pure Ti are obviously improved using a high–ratio differential speed rolling (HRDSR) [9,10]. However, the bending curvature of the ASR–processed plate is dramatically increased with increasing SR, which limits its application in continuous multi-pass rolling [12]. Recently, researchers studied the effects of rolling route on the microstructural evolution and mechanical performance. Chino [13] thought that specimens processed by reverse and cross rolling exhibited higher formability of Mg alloy than the specimen processed by the unidirectional rolling. Gholinia [14] studied the influences of deformation routes on the accumulation of shear deformation in equal channel angular extrusion (ECAE) process, and found that the effective strain and final deformed microstructures strongly depended on the deformation routes. The effect of deformation routes on the microstructure evolution mainly depend on the alternative shear plane and direction between strain increments. As known that redundant shear strains are an important feature of the deformation through-thickness regions both in ECAP and ASR operations. Therefore, the effects of deformation routes on the accumulation

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https://doi.org/10.1016/j.msea.2018.07.060
Received 6 December 2017; Received in revised form 16 July 2018; Accepted 17 July 2018
Available online 18 July 2018
0921-5093/

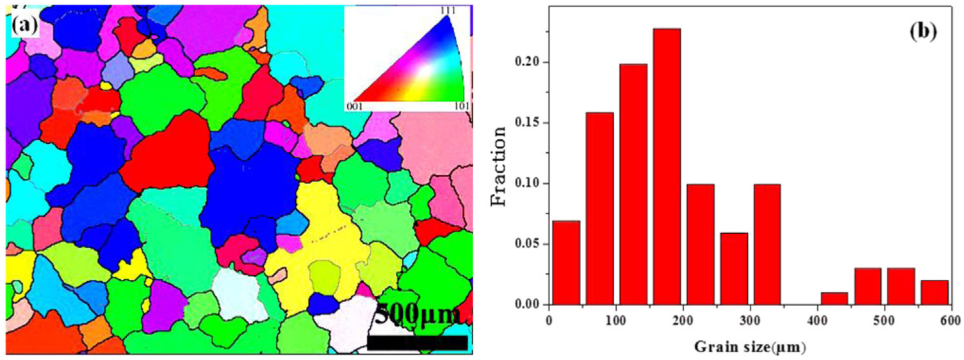

Fig. 1. Microstructure (a) and grain size distribution (b) of the homogenized 7050 Al alloy.

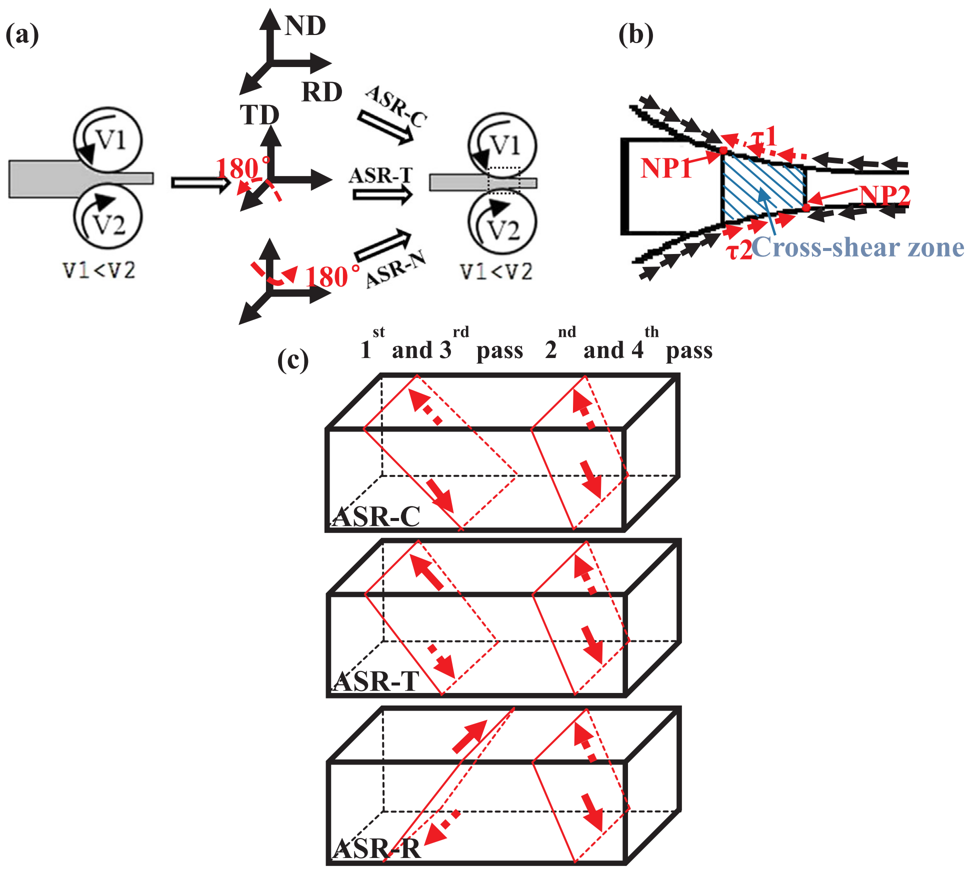

Fig. 2. Three ASR processing routes (a), Friction stress (τ1, τ2) distribution in the deformation zones during ASR processing (b), and (c) shearing patterns in the cross-shear zones of the multi-pass ASR-processed plates with three ASR routes.

of strains , microstructures evolution and the through thickness property variations in ASR are necessary to be studied.

The present study aims to investigate the effects of three deformation routes (rotating the samples 180° with transverse / rolling direction, and no rotation between the adjacent passes) on the strains, microstructures and mechanical properties of the ASR–deformed 7050 Al alloy plates. Meanwhile, the shearing patterns between the adjacent passes for the different deformation routes are discussed.

2. Experimental procedure

The starting plates with 20 mm thickness were cut from a 7050 Al alloy ingot (Al-6.13Zn-2.0Mg-2.1Cu in mass %) and then homogenized at 475 °C for 24 h followed by air cooling. The homogenized plates possessed coarse equiaxed grains of around 160 μm in average size as shown in Fig. 1. The ASR processing was conducted at a rotation speed ratio of 1.25 without lubrication on the roll surfaces. Both of the rolls with a diameter of 400 mm and the lower roll rotates at a speed 25% faster than the upper one. The plates were rolled from 20 to 5 mm in thickness by 4 passes at 430 °C and the detailed rolling schedule is shown in our previous study [5]. Three ASR deformation routes were illustrated schematically in Fig. 2a which are designated as ASR-C, ASR-T and ASR-R. For ASR-C route, the plate was ASR-processed consecutively with the same strain path each pass, but for ASR-T and ASR-