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Development of ultrafine-grained Al 6063 alloy by cryorolling with the optimized initial heat treatment conditions

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ABSTRACT

The effects of rolling temperature and rolling strain on the microstructural refinement of Al 6063 alloy are investigated in the present work by employing electron back scattered diffraction (EBSD) analysis, transmission electron microscope (TEM) investigations, and X-ray diffraction (XRD) analysis. The solution treated bulk Al 6063 alloy samples are subjected to cryorolling and room temperature rolling to produce sheets with different strain levels such as 0.4, 2.3 and 3.8, respectively. Prior to cryorolling and room temperature rolling, the initial conditions such as solution treatment temperature, and sample immersion duration time, in liquid nitrogen, before cryorolling are optimized by using EBSD analysis, TEM investigations, hardness test, and tensile test. It is observed that the formation of recrystallized ultrafine-grains with the high angle grain boundaries occurs at the strain value of 3.8. However, in case of room temperature rolled samples, the sub-grains are not recrystallized even up to the strain value of 3.8.

1. Introduction

Ultrafine-grained (UFG) metallic materials with the grain size of less than 1 μm have received considerable research interests due to their superior mechanical properties such as higher strength and ductility as compared to that of its bulk materials. Severe plastic deformation (SPD) is an emerging method for the production of UFG structures in bulk metals and alloys [1–5]. However, a requirement of high plastic strain for the grain refinement and the difficulties in producing long length products in ultrafine-grained materials limits the use of SPD.

Aluminium alloys are widely used in the form of sheets and plates for various structural applications. In order to produce sheets or plates of ultrafine-grained Al alloys in large quantities for structural applications, the conventional route especially a rolling may be a viable option. Many researchers [6–11] investigated the microstructural features of the rolled face-centered cubic metals, with medium to high stacking fault energies, such as Cu and Al. They found it difficult to produce UFG structure especially in Al, through conventional rolling process, due to its high stacking fault energy and the reduced driving force available for recrystallization. To obviate these difficulties, conventional rolling at cryogenic temperature (cryorolling) has been identified as one of the potential routes to produce nanostructured/ultrafine-grained materials [12–18] from its bulk metals and alloys. The development of UFG microstructure in all these materials, except Cu, is obtained by implementing a combined treatment of cryorolling and annealing [12]. However, the UFG microstructure is obtained by cryorolling in Cu without subjecting it to any annealing treatment due to grain subdivision caused by twinning. Panigrahi et al. [19–22] investigated the mechanical and microstructural characteristics of cryorolled Al 6061, Al 6063, Al 7075 alloys.

The 6XXX series of Al alloys are extensively used in structural applications due to their good mechanical properties, higher corrosion resistance, better weldability and lower cost compared to 2XXX and 7XXX Al alloys [20]. Hence, Al 6063 alloy was selected as a model material from 6XXX series of alloys for cryorolling in the present work. Since the Al alloys (6XXX series) are precipitation hardenable, the solute elements such as Mg, Si, Fe and Cu in these alloys pin the dislocations and thus could decrease the rate of dynamic recovery during processing at liquid nitrogen temperature. Therefore, a selection of proper solution treatment condition of 6XXX series alloy prior to cryorolling is very much essential to suppress the dynamic recovery by altering the solute content in the solid solution. Also, for the manufacturing of Al 6063 alloy sheets for high strength structural applications, a sufficient amount of solute content in solid solution prior to plastic deformation is a necessary condition for enhancing mechanical properties of the processed sheets further upon proper ageing treatment. Therefore, it is vital to identify the proper solution treatment (ST) temperature and time to dissolve all the second phase particles in the

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