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Tensile and impact-toughness behaviour of cryorolled Al 7075 alloy

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ABSTRACT

The effects of cryorolling and optimum heat treatment (short annealing + ageing) on tensile and impact-toughness behaviour of Al 7075 alloy have been investigated in the present work. The Al 7075 alloy was rolled for different thickness reductions (40% and 70%) at cryogenic (liquid nitrogen) temperature and its mechanical properties were studied by using tensile testing, hardness, and Charpy impact testing. The microstructural characterization of the alloy was carried out by using field emission scanning electron microscopy (FE-SEM). The cryorolled Al alloy after 70% thickness reduction exhibits ultrafine grain structure as observed from its FE-SEM micrographs. It is observed that the yield strength and impact toughness of the cryorolled material up to 70% thickness reduction have increased by 108% and 60% respectively compared to the starting material. The improved tensile strength and impact toughness of the cryorolled Al alloy is due to grain refinement, grain fragments with high angle boundaries, and ultrafine grain formation by multiple cryorolling passes. Scanning electron microscopy (SEM) analysis of the fracture surfaces of impact testing carried out on the samples in the temperature range of −200 to 100 °C exhibits ductile to brittle transition. cryorolled samples were subjected to short annealing for 5 min at, 170 °C, and 150 °C followed by ageing at 140 °C and 120 °C for both 40% and 70% reduced samples. The combined effect of short annealing and ageing, improved the strength and ductility of cryorolled samples, which is due to precipitation hardening and subgrain coarsening mechanism respectively. On the otherhand, impact strength of the cryorolled Al alloy has decreased due to high strain rate involved during impact loading.

1. Introduction

Severe plastic deformation (SPD) techniques are now widely used for the production of ultrafine grained (UFG) microstructures in bulk metals. A unique advantage of these techniques is due to the possibility of developing fully dense nanostructured and ultrafine grained materials without the introduction of any contaminants. For example, severe plastic deformation (SPD) processes such as equal channel angular pressing (ECAP), multiple compression, accumulative roll bonding, and severe torsional straining are given lot of focus for the development bulk nanostructured metals for structural and functional applications. The SPD methods impart very large deformations to the samples at relatively low temperatures under high pressures [1,2]. However, majority of these methods require large plastic deformations with strains much larger than unity and scaling up of these processes is difficult. Almost 46% of aluminum alloys are used in the form of sheet and foil as reported in the literature [3]. Conventional rolling could be a suitable technique for the commercial production of bulk ultrafine grained Al alloys sheets but due to dynamic recovery and high stacking fault energy of Al and its alloys, it is difficult to produce ultrafine grained microstructures in the samples. To overcome these constraints, cryorolling has been identified as one of the potential routes for producing nanostructured/ultrafine grained pure metals Cu, Al, Ni [1,2,4] and Al alloys [5–7] from its bulk alloys. Rolling of pure metals and alloys in cryogenic temperature suppresses dynamic recovery and the density of accumulated dislocations reaches a higher steady state level as compared to room temperature rolling. With the multiple cryorolling (CR) passes, these higher density of dislocations rearrange themselves into sub-structures followed by the formation of ultrafine grain structures (ufg) with high angle grain boundaries [8,9].

Fracture and impact-toughness behaviours of aluminum alloys are of great technological importance for ensuring safe material design in structural applications. The aluminum alloys (7XXX) have been widely used as structural materials due to their excellent properties such as low density, high strength, ductility, impact toughness, fracture toughness and resistance to fatigue [10–14]. The cryorolled (CR) Al 7075 alloy exhibited the improved tensile, and hardness properties compared to room temperature rolled Al alloy as reported in the literature [3]. Precipitation kinetics of the

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