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Effect of immersion duration in liquid nitrogen for cryorolled A5052 aluminium sheet alloy

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Abstract

In this paper the effect of immersion duration on mechanical properties of cyrolled and non-cryorolled A5052 aluminium sheet alloy were studied. The sheets with and without annealing were rolled up to 30 % reduction at liquid nitrogen temperature. The mechanical behaviour of the sample were evaluated through hardness and tensile tests performed at room temperature. The evolution of microstructure was investigated using optical microscopy (OM). The optimum immersion duration of A5052 Al sheet alloy was 60 minutes as the hardness, tensile and yield strength were the highest for annealed sample with and without directly cryorolled. All the cryorolled samples showed elongated grain.

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Keywords: Cryorolling; 5052 Aluminium alloy; annealing

1. Introduction

Aluminum alloys are broadly utilized for manufacturing high strength and light weight structures in automotive and aerospace applications. The non-heat treatable wrought Al-Mg alloys (5xxx) are utilized for components that require greater design efficiency, better welding attributes, great superplasticity, high resistance to corrosion, and relatively high strength-to-weight ratio coupled with minimum cost[1].

In order to obtain sheets of ultrafine-grained Al alloys in large amount for structural applications, the conventional rolling may be a viable choice. However, it is hard to create UFG structure particularly for aluminium through conventional rolling process, because of its high stacking fault energy and the decreased driving force available for

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recrystallization[2]. Cryorolling has been identified as one of the potential routes to produce ultrafine-grained materials from its bulk metals and alloys in order to hinder these difficulties.

Cryorolling is a simple low-temperature rolling process in which the low temperature is maintained by liquid nitrogen[3]. It is a unique mechanical deformation process at cryogenic temperatures by which high strength and ductility combinations can be achieved. In cryorolling process, the material cools, its molecular structure contracts and hence there is entanglement of dislocations near the grain boundaries[4]. The suppression of dynamic recovery in the materials due to rolling at the cryogenic temperature causes density of accumulated dislocations to reach a higher steady state level, which in turn acts as a driving force for the formation of sub-microcrystalline or ultrafine grain structures (UFG) during subsequent annealing treatment[5].

The immersion duration of A5052 Al sheet alloy in the liquid nitrogen affects the amount of contraction of aluminium matrix and hence contributed to the improvement of hardness and strength value. Therefore, selection of suitable immersion duration is essential to obtain better mechanical properties of A5052 sheet alloy. In this study, the immersion duration was studied in order to determine optimum duration for dipping A5052 Al sheet alloy in the liquid nitrogen.

2. Experimental

A commercial A5052 Al sheet alloy used for structural applications was chosen for the present work. The chemical compositions of Al alloy are 1.83 wt% Mg, 0.37 wt% Si, 0.33 wt% Fe, 0.14 wt% Cr, 0.01 wt% Ga, 0.007 wt% Ni, 0.004 wt% Zn and Al balance. The A5052 Al sheet alloy plates were machined into the dimensions of 1.2 mm x 20 mm x 50 mm. The materials with different condition were investigated to study the effect of annealed, cryorolled and combination of annealed and cryorolled at various immersion duration in liquid nitrogen.

The A5052 Al sheet alloy was annealed at 300 °C for 2 h. The specimens of raw A5052 Al sheet alloy and in annealed condition were cryorolled up to 30% thickness reduction.

Initially, the samples were dipped in liquid nitrogen at different immersion duration such as 10 min, 20 min, 30 min, 60 min, 90 min and 120 min. To investigate the effect of immersion duration on the mechanical properties of A5052 Al sheet alloy, microhardness and tensile tests were carried out on the cryorolled and non-cryorolled samples dipped in liquid nitrogen for the different immersion duration times. Vickers hardness testing was performed at room temperature using 100 gf load and a dwell time of 10 seconds. To obtain Vickers hardness, minimum of five readings were taken on the well-polished surface parallel to the rolling direction. For tensile tests, the specimens were machined into the ASTM subsize specimen of 25 mm gauge length. Uniaxial tensile tests were conducted with the initial strain rate of 1 mm/min on Instron Universal Testing Machine operating at a constant crosshead speed. .

Microstructural characterization of the A5052 Al sheet alloy samples before and after rolled at cryogenic temperatures were subjected to microscopic studies. The microstructures of the sample were revealed by chemical etching with Keller's reagent and were examined using the optical microscope.

3. Result and discussion

3.1. Hardness properties

Fig. 1 shows the hardness properties of raw, annealed, cryorolled raw, and cryorolled annealed of A5052 sheet alloy samples at different sample immersion durations in liquid nitrogen temperature prior to each cryorolling pass. When the samples (raw material, annealed, cryorolled) immersion duration in liquid nitrogen prior cryorolling process was increased from 10 minute to 30 minute, significant improvement in the hardness for all the samples were observed. The improvement in hardness is due to prolong immersion duration in liquid nitrogen which increase the volume contraction of aluminium matrix causing the shrink of the microporosities and voids inside the sample[6]. The hardness of the samples (annealed and cryorolled annealed) achieved the highest hardness at immersion duration of 60 minutes and the hardness dropped as the immersion duration increase to 120 minute. For the high hardness value obtained at 60 minute immersion duration, it is considered the suitable immersion duration because all the microporosities and