Materials and Design 32 (2011) 1657–1666

Contents lists available at ScienceDirect

Materials and Design

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

Technical Report

Microstructure and microtextural studies of friction stir welded aluminium alloy 5052

N.T. Kumbhar [a], S.K. Sahoo [b], I. Samajdar [b], G.K. Dey [a], K. Bhanumurthy [c,*]

[a] Materials Science Division, Bhabha Atomic Research Centre, Mumbai 400 085, India
[b] Dept. of Metallurgical Engineering and Materials Science, Indian Institute of Technology, Mumbai 400 076, India
[c] Scientific Information Resource Division, Bhabha Atomic Research Centre, Mumbai 400 085, India

ARTICLE INFO

Article history:
Received 3 June 2010
Accepted 9 October 2010
Available online 14 October 2010

ABSTRACT

The present investigation presents a composite picture of the microstructural developments in a friction stir welded (FSW) AA5052. Optimized, defect free and chemically homogeneous, FS weld was generalized in four regions – base material (BM), nugget, advancing side (AS) and retreating side (RS), using standard nomenclatures. Each region had its signature of microstructural features. AS had clear indications of shear and of grain fragmentation. The nugget region, on the other hand, had nearly equiaxed grains, with strong in-grain misorientation and presence of grain-interior dislocation structure ruling out contributions from static recrystallization. Equiaxed grains of the nugget region had typical onion ring structure – each ring did approximately correspond to one dominant family of orientation. Microstructural developments, as obtained from relative grain refinement, in-grain misorientation development, relative banding, etc., were most significant in nugget followed by AS and then by RS. Heterogeneous plastic deformation and thermal activation through localized heating/friction were the apparent causes. Most of the friction stir welded specimen fractured away from the nugget and showed ductile mode of failure.

1. Introduction

In a conventional welding process, aluminum alloys are typically classified as 'difficult to weld' [1]. The difficulty is often attributed to the solidification process and structure – including loss of alloying elements and presence of segregation and porosities [2]. Friction stir welding (FSW) offers an alternative through solid-state bonding, which eliminates all these problems of solidification associated with the conventional fusion welding processes [3]. Different aspects of microstructural developments [4–14] and linking such developments with properties [15–22] have often been the focus of today's research on FSW. The different microstructural aspects include grain structure evolution, texture development, temperature distribution, recrystallization mechanisms, precipitation phenomena, etc. These factors also influence the strength and quality of the FS welds which are assessed in various environments – tensile loading, corrosion, fatigue, residual stress, etc.

It is known that the friction stir welding of solid solution hardened alloys does not result in softening. This is because of various microstructural factors including grain size [6,23,24], particle size and their distribution [23] and dislocation density (strain hardening being the main hardening mechanism) [25,26] contributing to the hardness in the welds of solid solution hardened alloys. Examining the relationship between microstructure and fracture limit strain of plane strain deformation, Sato et al. [24] concluded that large grain size and low density of dislocations and subboundaries were requisite for excellent plane strain values in the nugget of FSW 5052 Al alloy. Based on the analysis of Hall–Petch relationship, Sato et al. [25] found that the hardness profiles in the FS weld zone of Al 5083 alloy could not be explained alone by the grain size in the weld. Contributions of small Al_6(Mn, Fe) (dispersoid) particles in the grain interiors via the Orowan mechanism were also observed. In addition, studies on friction stir processing of 5052 Al alloy and its effect on the microstructure and texture have been reported using two-dimensional orientation imaging microscopy (2D OIM) and three-dimensional orientation imaging microscopy (3D OIM) technique [27,28]. Park et al. [29] used the surface friction stirring method to improve the formability performance of AA5052-H32 by aligning the stirred zone such that it is along the major tensile principal strain direction. However improved spring-back performance was found regardless of the arrangement of the stirred zone. It is clear from these studies that detailed metallurgical aspects including microstructure and evaluation of mechanical properties are not well attempted.

The aim of the study is to provide a composite picture of microstructural development associated with FSW of AA5052 and correlate these with the associated mechanical (mainly tensile) properties.

* Corresponding author.
E-mail address: aditya@barc.gov.in (K. Bhanumurthy).

0261-3069/$ - see front matter
doi:10.1016/j.matdes.2010.10.010