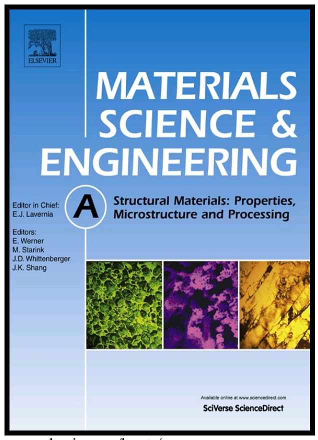
Author's Accepted Manuscript



www.elsevier.com/locate/msea

Superplasticity of friction-stir welded AL-Mg-SC sheets with ultrafine-grained microstructure

S. Malopheyev, S. Mironov, I. Vysotskiy, R. Kaibyshev

PII: S0921-5093(15)30443-3
DOI: http://dx.doi.org/10.1016/j.msea.2015.09.106
Reference: MSA32832

To appear in: *Materials Science & Engineering A*

Received date: 30 June 2015
Revised date: 23 September 2015
Accepted date: 27 September 2015

Cite this article as: S. Malopheyev, S. Mironov, I. Vysotskiy and R. Kaibyshev, Superplasticity of friction-stir welded AL-Mg-SC sheets with ultrafine-graine microstructure, *Materials Science & Engineering A* http://dx.doi.org/10.1016/j.msea.2015.09.106

Superplasticity of friction-stir welded Al-Mg-Sc sheets with ultrafine-grained microstructure

S. Malopheyev[1,a,*], S. Mironov[2,b], I. Vysotskiy[1,c], R. Kaibyshev[1,d]

[1]Laboratory of Mechanical Properties of Nanoscale Materials and Superalloys, Belgorod State University, Pobeda 85, Belgorod 308015, Russia
[2]Department of Materials Processing, Graduate School of Engineering, Tohoku University, 6-6-02 Aramaki-aza-Aoba, Sendai 980-8579, Japan
[a]malofeev@bsu.edu.ru, [b]smironov@material.tohoku.ac.jp, [c]visotsky@bsu.edu.ru, [d]rustam_kaibyshev@bsu.edu.ru
*corresponding author

The commercial Al-5.4Mg-0.2Sc-0.1Zr alloy was subjected to equal-channel angular pressing at 300 °C to a true strain of ~12 followed by cold rolling to a total thickness reduction of 80%. The produced ultrafine-grained sheets were joined by friction stir welding (FSW). To evaluate the superplastic properties of the obtained joints, the tensile samples including all of the characteristic FSW microstructural zones were machined perpendicular to the welding direction and pulled up to failure in the temperature range of 400 to 475 °C with initial strain rates of 2.8×10^{-3} s^{-1} to 5.6×10^{-1} s^{-2}. The friction-stir welded material exhibited superplasticity over the entire studied range. However, material flow was found to be mainly localized in the stir zone of the joints, whereas it was almost completely retarded in the base material zone. This effect was attributed to the work-hardened nature of the base material and to its propensity for abnormal grain growth.

Keywords: Aluminum alloys; Severe plastic deformation; Ultrafine-grained materials; Friction stir welding; Superplasticity

1. Introduction

Al-Mg-Sc alloys belong to a new class of high-performance aluminum alloys developed for applications in the aerospace industry [1]. Minor additions of Sc to an Al-Mg solution lead to the formation of well-distributed nano-scale coherent Al_3Sc precipitations, which are thermodynamically stable. These particles are very effective in pinning of the dislocations and grain boundaries and thus impart a significant strengthening and promote microstructure stabilization [2]. The superior properties of these materials could further be improved via the formation of an ultrafine-grained (UFG) microstructure. Severe plastic deformation (SPD) is well accepted as one of the most effective approaches for this purpose [3, 4]. Among various SPD methods, equal-channel angular pressing (ECAP) appears to be particularly attractive due to its relative simplicity and its ability to produce UFG structure in large-scale billets [4]. These characteristics enable the combination of this technique with conventional thermo-mechanical processing (rolling, extrusion, etc.) for commercial production of the UFG semi-finished products. Such semi-finished products are believed to be very attractive for high-strain-rate superplastic forming [e.g., 5, 6].

In practice, the production of complex details and components may require superplastic forming of welded structures. Moreover, welding makes feasible the production of superplastic sheets with dimensions larger than those of rolled sheets. Conventional fusion welding technologies cannot retain the UFG structure and the nano-scale dispersoids and thus inevitably lead to degradation of the unique properties of these materials [7-9]. Therefore, the conventional technologies are obviously not appropriate for this processing route. In contrast, the friction-stir welding (FSW) technique enables preservation of the fine-grained structure [10-14] and avoids dissolution of the unique Al_3Sc dispersoids [7-9, 14-20] in the weld zone, making FSW particularly promising for use in the joining of UFG Al-Mg-Sc alloys.

Recent studies have demonstrated that friction-stir processed Al-Mg-Sc alloys exhibit excellent superplastic properties [21-28]. Specifically, the maximum elongation-to-failure value may sometimes exceed 2000% [21, 24, 27]. It is important to emphasize, however, that a typical friction-stir joint includes several microstructural zones (i.e., base material, heat-affected zone, thermo-mechanically affected zone and stir zone), which may have distinctly different microstructures [29,