Materials Science & Engineering A 636 (2015) 326–330

Contents lists available at ScienceDirect

Materials Science & Engineering A

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

Rapid communication

Inhibition of abnormal grain growth during hot deformation behavior of friction stir processed 5083 Al alloys

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ARTICLE INFO

Article history:
Received 22 November 2014
Received in revised form
13 March 2015
Accepted 20 March 2015
Available online 1 April 2015

Keywords:
5083 Al alloys
Friction stir processing
Abnormal grain growth
Superplasticity

ABSTRACT

Friction stir processing (FSP) has demonstrated to refine the microstructure of different alloys resulting in superior mechanical properties. Abnormal grain growth (AGG) has been recognized as a critical issue during hot deformation of FSPed Al alloys. 5083 Al alloys with different Mn content were subjected to heat treatments at 350 and 535 °C before FSP to avoid AGG during subsequent hot deformation. As a result, heat treatment of 350 °C was able to retard AGG significantly. Also, an improvement in the refinement of the microstructure was observed. Consequently, a better ductility of 861% at elevated temperature was reached in the alloy with lower Mn content comparing with the same alloy without heat treatment prior to FSP.

1. Introduction

Friction stir processing (FSP) has been established as a remarkable technique for grain refinement [1]. It is an adaptation of friction stir welding (FSW) process invented by TWI in 1991 [2]. FSP can be used as a grain refinement technique for selected regions [1]. Recently, FSP has caused much interest as a tool for producing superplastic aluminum alloys due to the presence of a very fine grain size and high angle grain boundaries in FSPed metallic materials [1,3–6]. It has been noted that the extension of the superplasticity in FSPed aluminum alloys, despite the favorable microstructural features, comes to be limited by the evolution of thermally unstable microstructures at high temperatures. The ductility drops abruptly above a critical test temperature with an increase in flow stress due to the extreme microstructural instability [3,5–7]. In FSWed components, the evolution of a similar structure in the nugget has also been observed during the subsequent heat treatment, which is performed to restore the lost strength in the heat affected zone (HAZ) [8,9]. Such microstructural instability has been identified as abnormal grain growth (AGG). According to Humphreys and Hatherly [10], the excessive growth of a few grains at the expense of smaller recrystallized grains is known as AGG, also called secondary recrystallization since this discontinuous growth of selected grains is similar to the kinetics of the primary recrystallization. AGG in FSW/FSP has been studied, both experimentally and theoretically, however much of this research has been on heat treatments after FSW/FSP or seeking a relationship with processing parameters [5], as a result researchers have used the Humphreys model [10–13] on the cell microstructure stability to explain it. This paper developed from a previous work where the influence of FSP tool design on hot behavior of FSPed Al–Mg alloys was investigated [14]. In that work, abnormal grain growth was observed after applying FSP to an Al–Mg alloy using a FSP tool called T1. On the other side, good thermal stability of some FSPed samples in the same work was attributed to the dispersion of fine second phase particles pinning the grain boundaries in spite of being a non-heat-treatable Al alloy. Thus, a couple of heat treatments prior to FSP were proposed to try to reduce AGG. One heat treatment is at 350 °C and the other at 535 °C, both for 10 h. These treatments were applied to the alloy used in the previous study as well as to another alloy also

Table 1
Compositions of the alloys in weight percent (balance Al).

Alloy	Mg	Mn	Cr	Fe	Si
A	4.72	0.49	0.19	0.16	0.09
B	4.73	0.74	0.17	0.15	0.09

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http://dx.doi.org/10.1016/j.msea.2015.03.094
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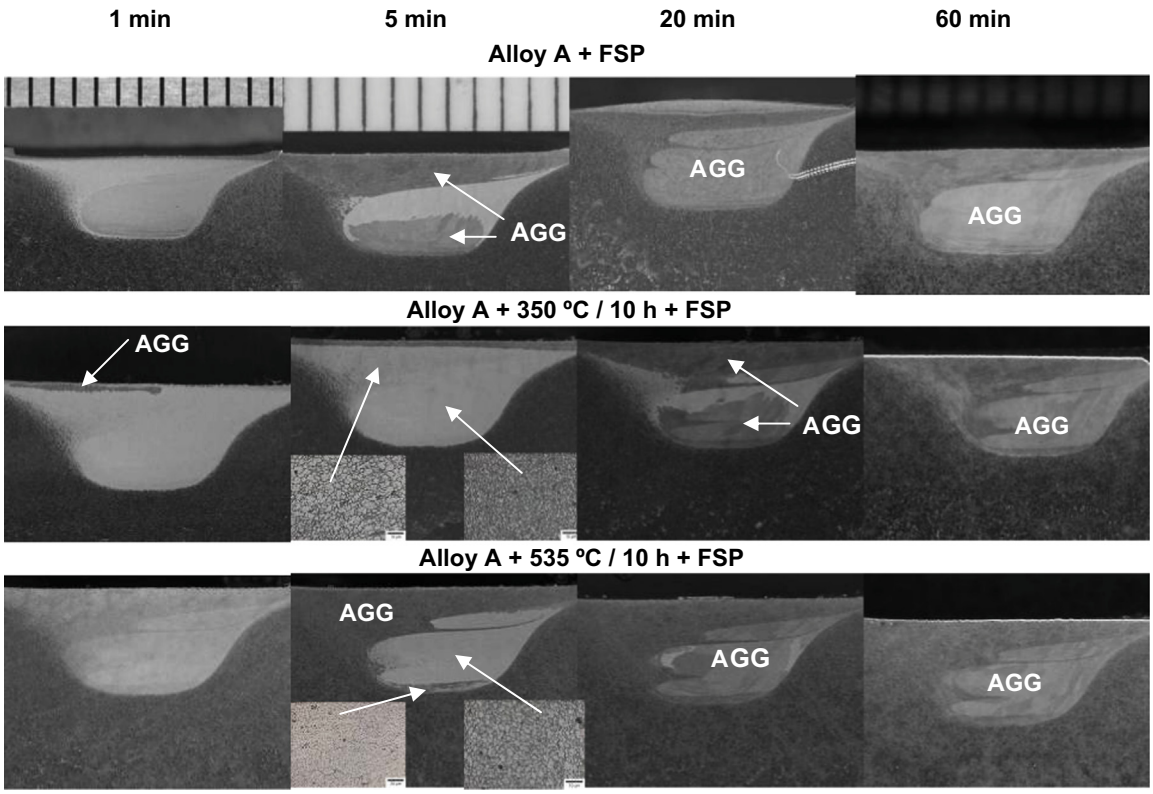

Fig. 1. Macrographs showing the traverse cross-section of FSPed alloy A, top-down: without previous heat treatment, with two different heat treatments at 350 and 535 °C/10 h prior to FSP. The samples were heat treated to 490 °C at different times to simulate superplastic conditions, from left to right.

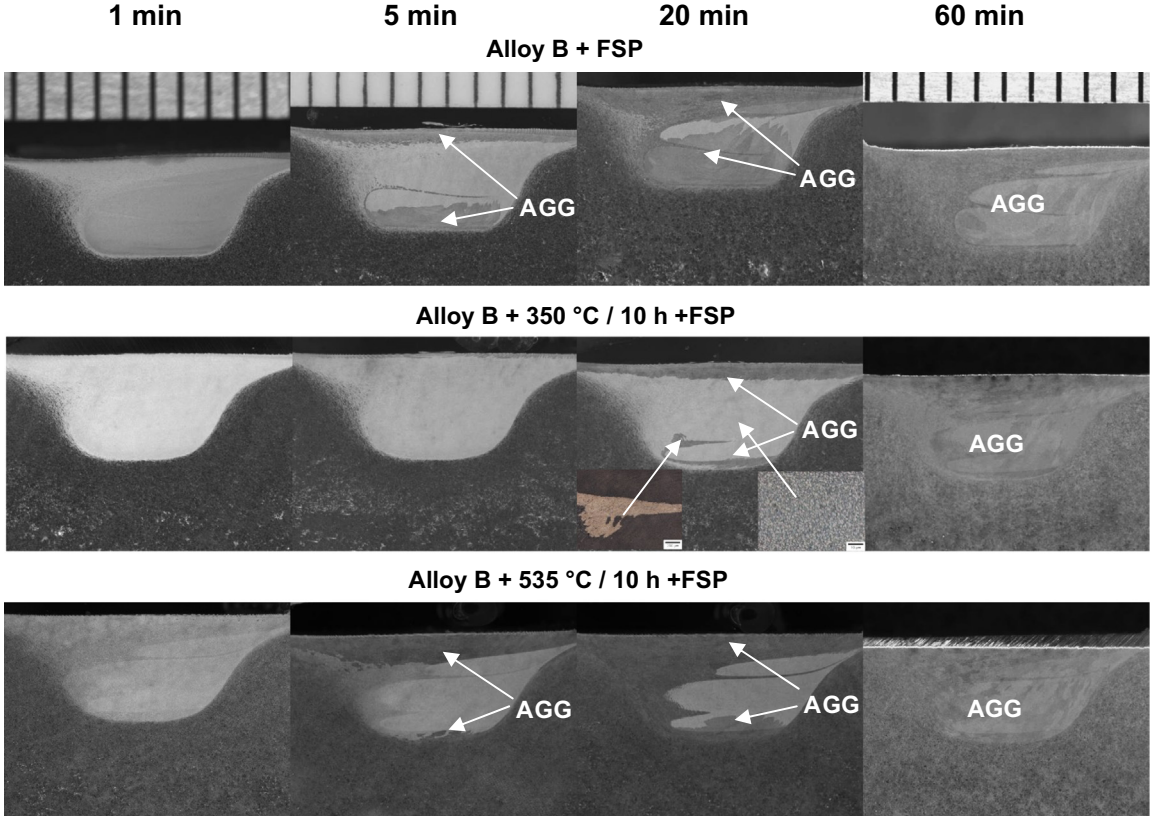

Fig. 2. Macrographs showing the traverse cross-section of FSPed alloy B, top-down: without previous heat treatment, with two different heat treatments at 350 and 535 °C/10 h prior to FSP. The samples were heat treated to 490 °C at different times to simulate superplastic conditions, from left to right.