Materials and Design 36 (2012) 123–129

Contents lists available at SciVerse ScienceDirect

Materials and Design

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

Plastic flow behaviour and formability of friction stir welded joints in AZ31 thin sheets obtained using the "pinless" tool configuration

A. Forcellese [a], M. Simoncini [b,*]

[a] Dipartimento di Ingegneria Industriale e Scienze Matematiche, Università Politecnica delle Marche, Ancona 60131, Italy
[b] Università degli Studi e-Campus, Via Isimbardi 10, 22060 Novedrate (CO), Italy

ARTICLE INFO

Article history:
Received 3 October 2011
Accepted 8 November 2011
Available online 15 November 2011

Keywords:
Welding
Forming
Plastic behaviour

ABSTRACT

The plastic flow behaviour and formability of friction stir welded AZ31 magnesium alloy sheets, 1.5 mm thick, were widely investigated. Flow curves were obtained in extended ranges of temperature (250–350 °C) and strain rate (10^{-3}–10^{-1} s^{-1}) by means of uniaxial tensile tests; furthermore, forming limit curves were determined using the hemispherical punch method at 350 °C, with a constant cross-head speed of 0.1 mm/s. The results were compared with those obtained on the base material, under the same experimental conditions. It has shown that the flow stress and ductility levels of joints are lower than those of base material; however, as temperature increases and strain rate decreases, the peak flow stress of the welded joint tends to be similar to the one of the base alloy. Finally, formability of the friction stir welded blanks, evaluated in terms of forming limit curves, is lower than the one of the base material.
© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

The development of lightweight components is a very important target aiming at reducing the structure weight. Such requirement is stringent in the automotive industry due to environmental regulations and fuel consumption reduction policies [1]. In the manufacturing of sheet metal assemblies, lightweight structures can be effectively obtained using tailor welded blanks (TWBs), consisting in flat sheet metal assemblies of two or more components, also in different materials and/or thicknesses. Such assemblies can be deformed, with an optimised thickness distribution, in order to get the desired geometry. TWBs offer several advantages in terms of part integration, weight reduction, improved structural performances, improved material utilisation, reduced spot weld assembly operations, etc. Their main drawback is the low formability, caused by the presence of welding lines in which micro- and/or macro-defects are usually located [2–4]. As a consequence, the welding technology strongly affects the forming behaviour of TWBs [5,6]. As far as traditional fusion welding processes (tungsten inert gas and metal inert gas) are concerned, the grain coarsening typically observed in the heat affected zone and the hardening of the welded joints strongly reduce the TWB formability; also, the loss in mechanical properties, as compared to the base material, is very significant [2,3].

In order to overcome the limitations of traditional arc welding, electron beam welding and laser welding technologies can be used [7–12], even though research efforts for developing new innovative welding techniques are in progress. Among them, friction stir welding (FSW) is a recent answer issued by the welding community to meet the need for more efficient processes providing high-quality joints [13–16]. The FSW is a solid state process in which a specially designed rotating tool, composed by a shoulder and a pin, is inserted into the edges of the sheets to be welded, with a proper tilt angle, until the shoulder gets in contact with the top surface of the sheets; then, the rotating tool is moved along the welding line. The combined effect of tool rotation and translation involves heat generation by friction between tool and sheets, and induces a strong plastic deformation of the workpiece promoting its complex mixing across the joint [15–24]. The energy efficiency, environment friendliness and versatility make the friction stir welding a promisingly ecologic and "green" technology. Actually, as compared to the fusion welding processes, FSW consumes less energy and leads to a decrease in material waste and to the avoidance of radiation and dangerous fumes [17]; moreover, FSW is able to produce a strong metallurgical bonding and has many technical advantages for joining soft materials, such as aluminium and magnesium alloys, that are very difficult to be welded using fusion technologies due to the insurgence of defects such as inclusions, voids or un-effective metallurgical structures [17–20,24].

As the post-welding formability of TWBs in Mg alloys is concerned, it should be taken into account the poor formability exhibited by such ultra-light alloys at room temperature due to their hcp structure and the improvement in formability with increasing

* Corresponding author. Tel.: +39 071 220 4798; fax: +39 071 220 4801.
E-mail addresses: a.forcellese@univpm.it (A. Forcellese), michela.simoncini@uniecampus.it, m.simoncini@univpm.it (M. Simoncini).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.11.017

process temperature owing to the activation of further sliding planes [25–36]. In previous papers [26,33], the authors focused on the post welding formability of FSWed joints in AZ31 Mg alloy, 3.2 mm thick sheets, emphasising the effects of temperature and strain rate on plastic flow behaviour and formability of joints.

The manufacturing of TWBs becomes ever more complex as sheet thickness decreases due to the reduction in thickness produced by the forging effect of the shoulder that, in turn, leads to a decrease in the mechanical strength of the weld; furthermore, the occurrence of micro-defects, due to the stirring action of the pin, that can be accepted on thicker sheets, leads to a further decrease in strength [37,38]. In order to overcome such difficulties, the FSW process can be performed using a "pinless" tool configuration in which the stirring action is absent due to the lack of the pin so that the heat flux during process is generated only by the frictional force at the tool shoulder–workpiece interface. However, the potential advantages offered by the "pinless" tool can be fully exploited only as thin sheets are welded since, as the thickness increases, the shoulder influence becomes ever more localised to the top sheet surface. Tang et al. [39] demonstrated that, with a "pinless" tool configuration, the value of maximum temperature occurring during FSW undergoes to a reduction equal to about 4% as compared to that reached using a "pin" tool under the same conditions; such result is indicative of the reduced influence of the pin on the heat input. In a previous work, the authors have investigated the effect of the tool configuration and welding parameters on strength and ductility of AZ31 FSWed joints with a sheet thickness of 1.5 mm. It was shown that the "pinless" configuration, with a proper shoulder diameter, leads to higher mechanical properties than the pin one confirming the effectiveness of the "pinless" tool configuration as thin sheets are concerned.

Due to the difficulty associated to the FSW on thin sheets, very few studies on ductility and formability of friction stir welded metal assemblies in thin sheets, less than 2 mm thick, are available in literature [37,38], whilst most of studies deals with sheet thicknesses ranging from 3 to 6 mm using the "pin" tool configuration [13–26,33].

In this framework, the present paper aims at studying the plastic flow behaviour and formability, under warm forming condition, of FSWed joints in AZ31 thin sheets, obtained using a "pinless" tool configuration. A preliminary investigation has allowed to define the rotational and welding speed values at which the FSW process produces joints with the highest micro- and macro-mechanical properties [40]. Then, the plastic flow curves of FSWed joints were obtained by means of tensile tests performed in extended ranges of temperature and strain rate. Forming limit curves (FLCs) were also evaluated using the hemispherical punch method. The results were compared with those obtained, under the same experimental conditions, on the base material (BM). The flow stress levels and ductility of FSWed blanks are lower than those of base material, even if the peak flow stress of the joint tends to be similar to the one of the base alloy with increasing temperature and decreasing strain rate. Finally, formability of the friction stir welded blanks is usually lower than the one of the base material, in particular in the drawing side of the forming limit diagram (FLD).

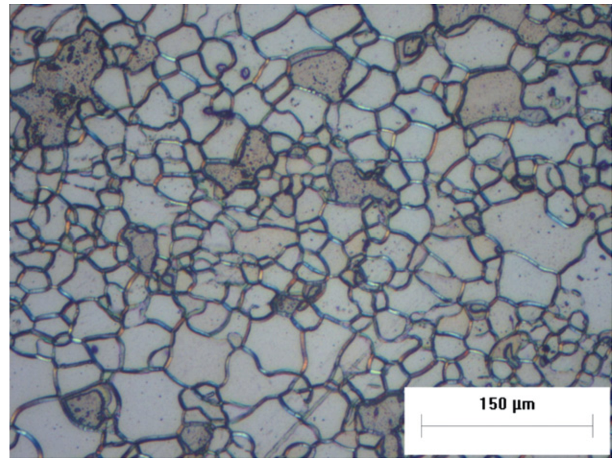

Fig. 1. Microstructure of the AZ31 magnesium alloy sheet in the as-received condition, obtained in the cross section perpendicular to the rolling direction.

2. Experimental procedures

2.1. Material

Thin sheets in AZ31 magnesium alloy, with a thickness of 1.5 mm, were investigated in the present work. The alloy, provided in the as-received condition, was characterised by an initial mean grain size of 29.95 µm (Fig. 1) and a micro-hardness value equal to 68 HV.

2.2. Friction stir welding

Friction stir welding of AZ31 alloy was carried out in a CNC machining centre using a tooling in H13 tool steel (HRC = 52), char-

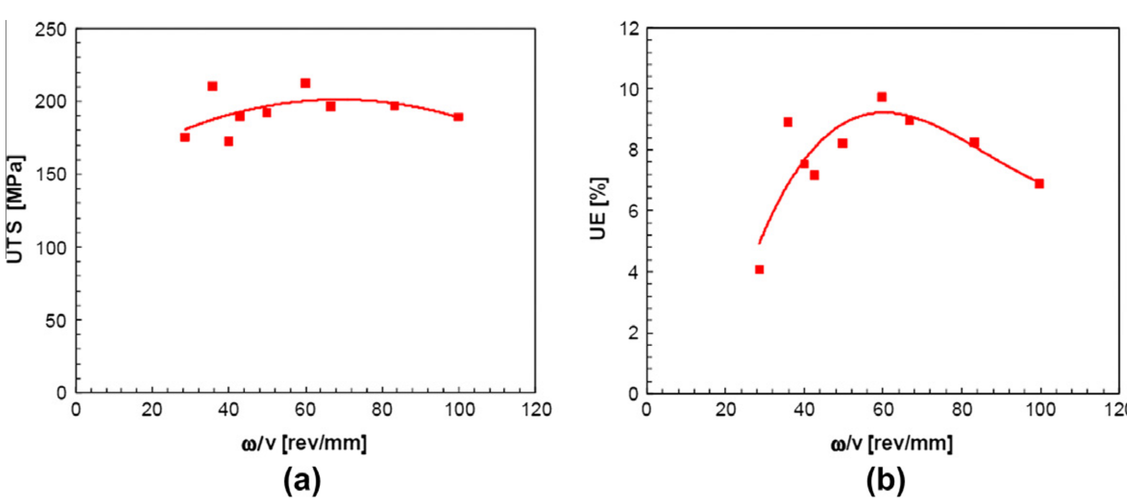

Fig. 2. (a) Ultimate tensile strength and (b) ultimate elongation values provided by uniaxial tensile tests at room temperature, performed on FSWed joints obtained using the pinless tool configuration, as a function of the rotational/welding speed ratio.

Download English Version:

https://daneshyari.com/en/article/830822

Download Persian Version:

https://daneshyari.com/article/830822

Daneshyari.com