Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 207 (2017) 591–596

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on the Technology of Plasticity, ICTP 2017, 17-22 September 2017, Cambridge, United Kingdom

The influence of process parameters on mechanical properties and corrosion behaviour of friction stir welded aluminum joints

Gianluca D'Urso[a]*, Claudio Giardini[a], Sergio Lorenzi[b,c], Marina Cabrini[b,c], Tommaso Pastore[b,c]

[a]University of Bergamo - DIGIP, Viale Marconi 5, Dalmine (BG)24044, Italy
[b]Consorzio INSTM, Via G. Giusti 9, Firenze (FI) 50121, Italy
[c]University of Bergamo - DISA, Viale Marconi 5, Dalmine (BG)24044, Italy,

Abstract

Aim of this study is to analyse how the process parameters affect the mechanical properties and the corrosion behaviour of butt joints obtained by friction stir welding (FSW). The experimental study was performed by the friction stir welding of sheets having a thickness equal to 4 mm and made of three aluminum alloys, namely AA7075, AA6060 and AA2024, considering all the combinations among the three materials and varying the process parameters, namely rotational speed and feed rate. Tensile tests were performed orthogonally to the welding direction on specimens having the welding nugget placed in the middle of gage length, while micro-Vickers tests were carried out on each specimen moving from the joint axis until the hardness of the base material was reached. The best conditions in terms of mechanical strength were obtained using the "intermediate" values of rotational speed, and, in general, when the process parameters result in low values feed rate per unit revolution (F/S), that corresponds to the higher thermal contribution to the joint region. Since in many industrial applications the mechanical resistance is not sufficient for completely describing the joint reliability, further local corrosion potential measurements and four-point bending tests were performed to evaluate the corrosion behaviour and stress corrosion cracking susceptibility of FSW Joints. The tests were carried out on prismatic specimens obtained by FSW joints of the same alloy (7075-7075 and 2024-2024) and mixed joints (7075-2024). No specimens failed during the test. It was observed that the lower the hardness, the more anodic the corrosion potential. In these zones an intense localized attack takes place in the HAZ due to the presence of precipitates. No systematic correlations between the parameters and the resistance to corrosion were observed. The presence of preferential corrosion sites was confirmed also by means of long time immersion tests.

Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.

* Corresponding author. Tel.: +39-035-205-2330; fax: +39-035-205-2043.
E-mail address: gianluca.d-urso@unibg.it

1877-7058
Peer-review under responsibility of the scientific committee of the International Conference on the Technology of Plasticity.
10.1016/j.proeng.2017.10.1026

Keywords: FSW; Aluminum alloys; Mechanical properties; Corrosion behaviour.

1. Introduction

Friction Stir Welding (FSW) technology, patented by TWI in 1991 [1,2], represents a valid solution for joining difficult to be welded materials (such as Al, Ti and Mg alloys but also Advanced High-Strength Steel [3]).

One of the most significant aspects of this technology is the achievement of the joining by maintaining the solid state of the material. The rotation of the tool and the movement along the joint axis cause an increase in material temperature (for the effect of friction between tool and workpiece and within the stirred material) and the plasticization of the material (for the combination of the mixing effect of the tool pin and the pressure applied by the tool shoulder) that cause the formation of a solid bonded region [4]. This technology permits the welding in several configurations and also the joining of dissimilar alloys [5-7] and it is used in several industrial applications such as automotive, aerospace and naval sectors [8,9].

The FSW technology has a large interest especially for high resistance aluminum alloys (e.g. 2000 and 7000 aluminum alloys series, because of their aeronautical use), which are difficult to be joined with traditional techniques which alter the microstructure obtained during age hardening. The high plastic flow and the heat generated by FSW may result in remarkable microstructural modifications and local changes of material characteristics [10,11].

For these reasons, it is very important to understand the effects of process parameters and process setup on the weld quality. Several Authors studied these aspects with particular attention to the quality of FSW joints in terms of mechanical properties (UTS, fatigue resistance etc.) [12-14]. For example, in [15] the Authors evidenced how some very important issues related to the mechanical properties of aluminum friction stir welded joints are process parameters such as feed rate, rotational speed, tool geometry and pin axis inclination. Tool rotational speed has been considered as one of the most important process variable: high rotational speeds may raise the strain rate, so affecting the re-crystallization process [16]. Moreover, some authors showed how high welding speeds are related to low heat inputs, which gives rise to faster cooling rates of the joint [17]. This can reduce the extent of metallurgical transformations taking place during welding (such as solubilisation, re-precipitation and coarsening of precipitates) and hence the local strength of individual regions across the weld zone. Based on these considerations, the ratio between the tool feed rate and the rotating speed can be considered as a relevant parameter in determining the mechanical strength of the joints. Other Authors observed that, welding by FSW A356 and 6061 aluminum alloys, the joint fabricated using low tool traversing and rotational speed, exhibits substantial improvement in bond strength [18]. In [19] empirical relationships have been developed to predict the tensile strengths of friction stir welded AA1100, AA2219-T87, AA2024-T3, AA6061-T6, AA7039-T4 and AA7075-T6 aluminum alloy joints. Other authors found that there is an optimal rotational speed range of the pin and that too low and too high speeds correspond to a low quality of the joints [20], demonstrating that these parameters can be optimized for obtaining sound parts.

In addition, particular attention has to be paid due to the well-known susceptibility of the copper-aluminum and zinc-aluminum alloys to stress corrosion cracking [21]. Despite the enhanced properties, the added elements introduce higher degree of heterogeneity due to the presence of secondary phases or termed constituent particles [22]. Corrosion behaviour can be mainly affected by the presence – size and distribution – of such phases, modifying the anodic and cathodic behaviour of the zones of joining. [23,24]. Several works describing corrosion morphologies that can occur also concomitantly in form of localized corrosion, e.g., galvanic corrosion, pitting, dealloying or intergranular attack [25-27] were found, but very few data regarding the combination of different alloys and the systematic correlation between mechanical properties and corrosion behaviour can be noticed. Under such considerations, the corrosion behaviour can be significantly influenced by welding parameters and a strict correlation between them and alloy macro and microstructure has to be further investigated [28].

As a general remark, it is possible to assert that the FSW process parameters have significant effects on the joint properties, sometimes different for dissimilar alloys, and their influence on the joint characteristics and behaviour is not yet fully understood.