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Texture in Welded Industrial Aluminum

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Abstract. In this investigation, grain orientation has been studied in an industrial aluminium Al99.5 which has been welded by TIG process. The optical microscopy and EBSD (Electron Back Scattered Diffraction) were the main techniques used to illustrate the effect of welding on grain orientation in fusion zone and in heat affected zone. Epitaxial growth has been observed in weld joint and texture of each zone has been determined. On the other hand, the effect of isothermal heat treatment at 400 °C on homogenization of welded joint has been also studied. It was shown that the cube orientation {001}<100> is the dominant texture component in welded joint before or after heat treatments.

Introduction

The microstructures and orientation distributions or textures produced when different manufacturing procedures such as rolling, extrusion, drawing, joining, and heat treatment are applied reflect the deformation mode and thermal history that the material experiences [1]. As reported by Cai et al [2], in recent years, great progress has been made in the studies about deformation texture of aluminum alloy. However, little works have been done to investigate texture formation in welded aluminum. For example, Hector et al [3], have studied the textural features produced in laser welded aluminum alloys. They have observed columnar grains that form on either side of the weld center lines and appear to grow out from the parent metal into the liquid are highly textured, with a <011> direction parallel to the growth direction. The most studies have focused on friction stir welds [4-6] and no studies appear to have examined texture development in Tungsten Inert Gas (TIG) welding of aluminum or aluminum alloys. The purpose of this investigation is to study the textural features produced during welding by TIG process of industrial aluminum sheet.

Experimental Procedures

The base material used in this study is industrial aluminum with chemical composition as indicated in table 1. Table 2 presents the chemical composition of the electrode which is used during welding by TIG process. Welding experiments were conducted by the use of inert gas, where the inputs were 100 V and 5 A.

Table 1 Chemical composition of aluminum (base metal).

Elt	Si	Fe	Cu	Zn	Ti	Other
Wt. **%**	0,30	0,40	0,05	0,07	0,05	0,03

Table 2 Chemical composition of the electrode.

Elt	Si	Fe	Cu	Mn	Zn	Ti	Mg	Other
Wt. %	<0,2	<0,25	<0,04	<0,03	<0,04	<0,03	<0,03	< 0,03

Specimens were prepared for Electron Back Scattered Diffraction (EBSD) analysis in the standard manner (SiC paper and A2 solution of Struers during 12s in 40V flux 12). A schematic of sample used for EBSD analysis in rolling direction is shown in figure 1. A Zeiss 940 SEM with a tungsten filament is used. The SEM device is coupled with the automatic OIM^{TM} (Orientation Imaging Microscopy) software from TSL company.

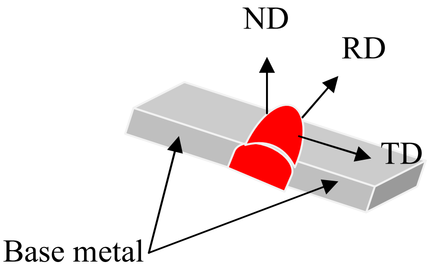

Fig.1 Specimen coordinate system.

The purpose of the EBSD experiments was to determine whether or not any significant texture resulted from the welding process and heat treatments. Optical Microscopy (OM) observations were performed after etching with Poulton solution: 12 ml HCl; 6 ml HNO_3; 1 ml HF (48%); 1 ml H_2O durant 15 s. For the temperature effect study on structural evolution in weld joint, our specimens have been annealed at isothermal temperatures (400 °C) during 4 hours.

Results and Discussion

Microstructure Evolution

In the first part of this paper, the microstructural features observed in different locations in welded joint of industrial aluminum before and after isothermal heat treatments are presented in figure 2. As it is known in welding, as the heat source interacts with the base metal, three distinct zones develop in the weldment: there is the fusion zone (FZ), also known as the weld metal, the heat-affected zone (HAZ), and unaffected base metal (BM). First of all, in our material there is a significant difference between three zones of welded joint, i.e., the microstructure of the fusion zone is characterized by the columnar grains, however the heat affected zone or base metal contains equiaxe-grains.

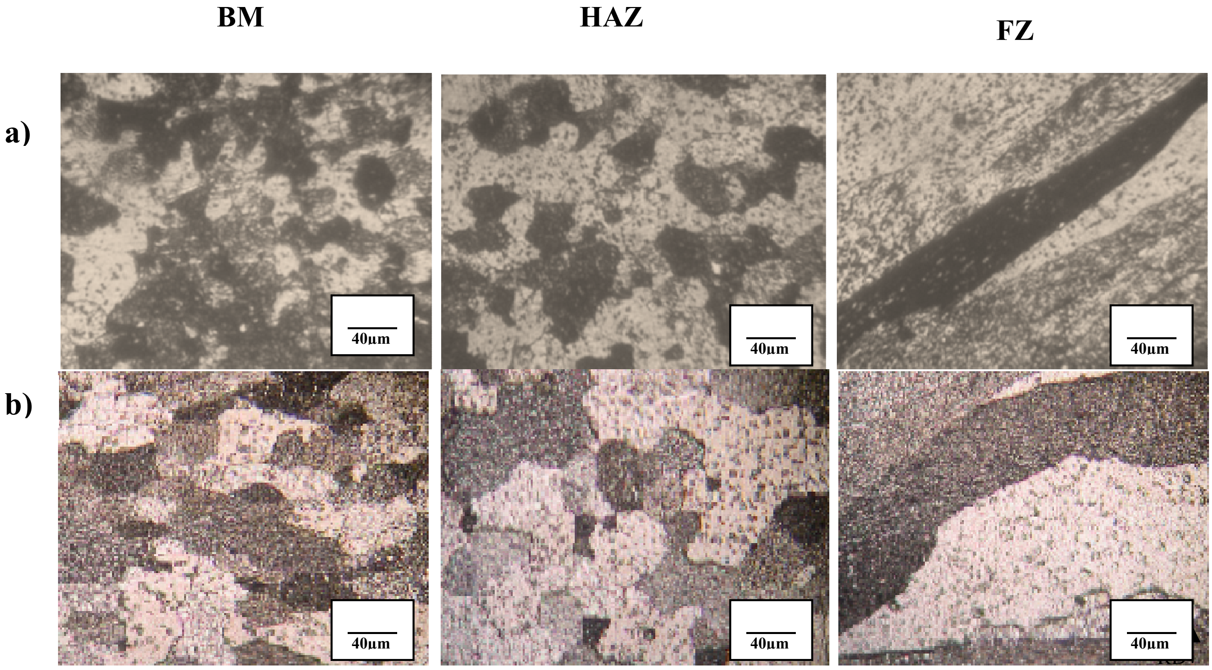

Fig. 2 Microstructures of welded joint (a) before and (b) after heat treatment at 400 °C during 4h.

Texture Evolution

The EBSD orientation color maps obtained in welded joint before and after heat treatment are also presented in figure 3. In this second part of this study, EBSD color maps of weld joint before heat treatments show also a significant difference between three zones(Fig.3a). In addition, Heat Affected Zone (HAZ) is characterized by a slight larger grain size than those in base metal. However, the fusion zone is totally different to other zones (HAZ, BM), because oriented grains are developed in this zone. This microstructure was due to the preferred mechanism of solidification after welding process which has been observed in previous works [3 - 7, 8]. For example, as indicated by David et al. [9], the microstructure in the FZ depends on the solidification behavior of the weld pool and it is more complicated [10,11] because of physical processes that occur due to the interaction of the heat source with the metal during welding. On the other hand, it is necessary to indicate that the heat treatment at 400 °C homogenizes microstructure between the base metal and the heat affected zone (Fig.3b).

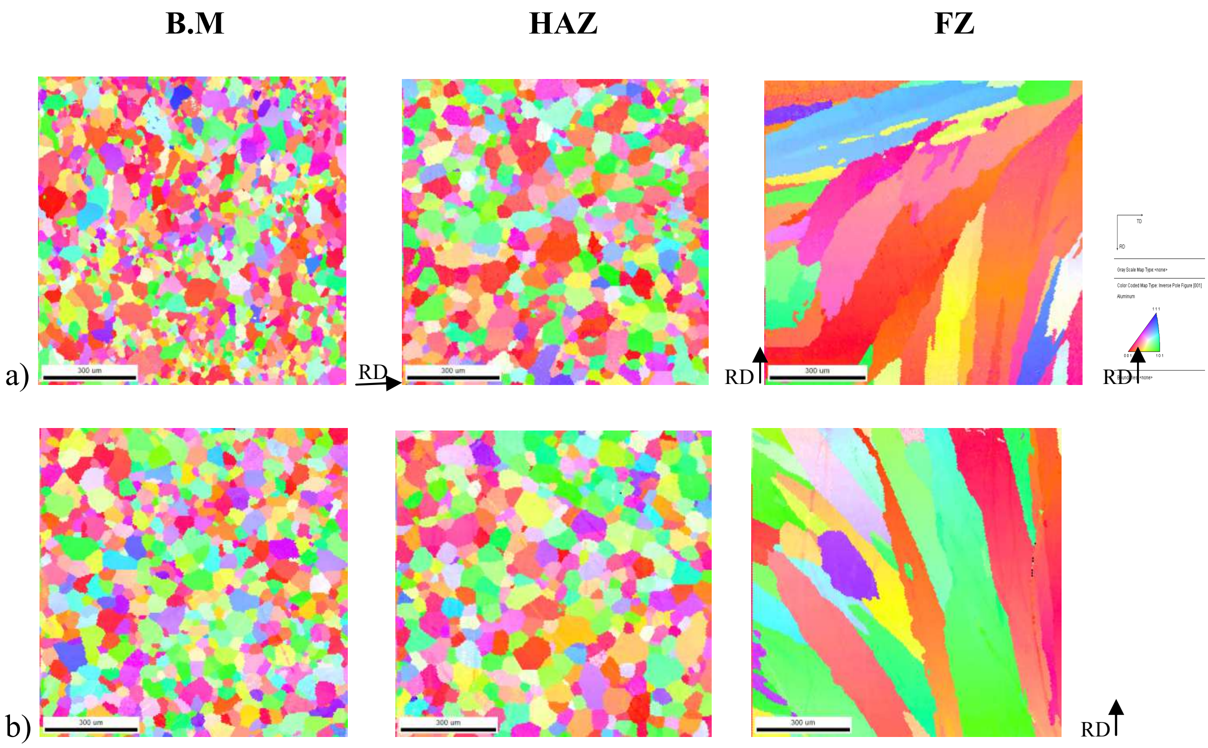

Fig. 3 EBSD color maps of welded joint (a) before and (b) after heat treatments during 4h at 400 °C.

Furthermore, pole figures at different zones of welded joint of industrial aluminum before and after heat treatments at 400 °C are shown in figure 4. The near cube texture appears in all zones of weld joint before (Fig. 4a) or after heat treatment or at 400 °C (Fig. 4b). As reported by Zaefferer et al [12], formation of the cube texture is also of interest as a model case to test the hypotheses of oriented growth and oriented nucleation as mechanisms of recrystallization texture formation. In comparison to the other zones in weld joint, the development of the same cube texture in fusion zone (FZ) confirms that these columnar grains grew from the base metal into the weld pool during cooling.

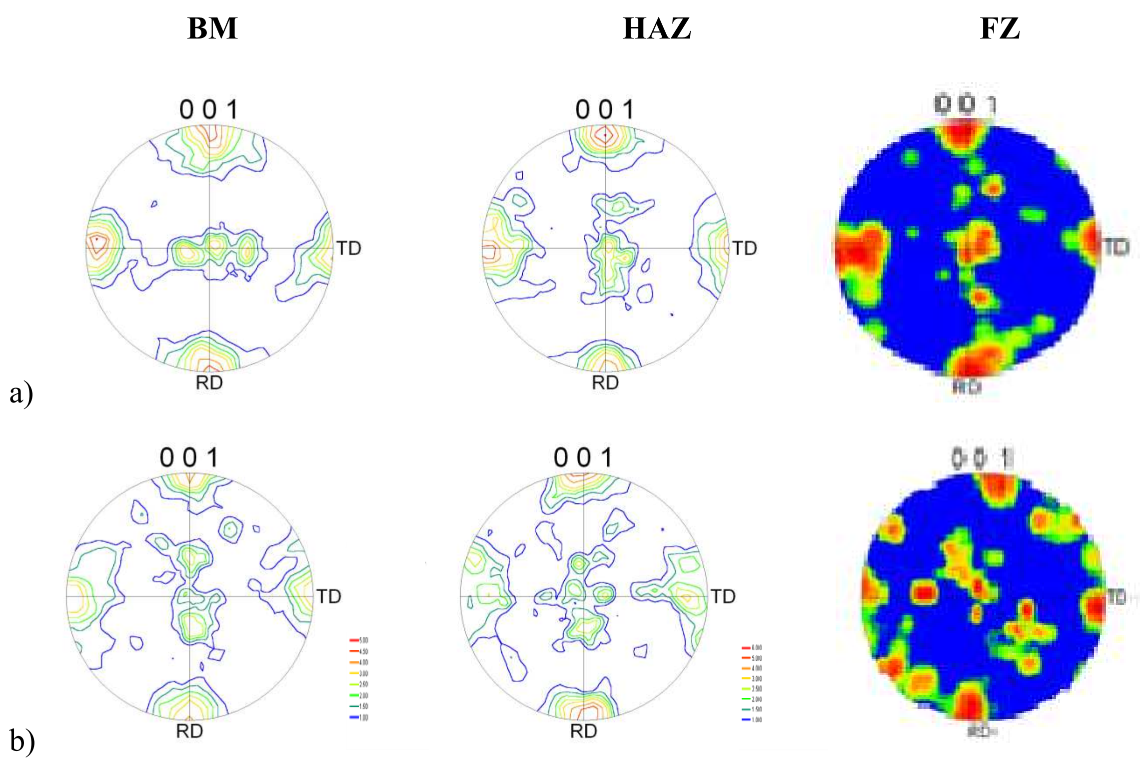

Fig. 4 {001} pole figures at different zones of weld joint (BM, HAZ and FZ) of industrial aluminium (a) before and (b) after heat treatment during 4h at 400°C.

The ODF results of previous samples are gathered in figure 5, which showing a strong cube orientation {001}<100> before or after heat treatments in different zones.

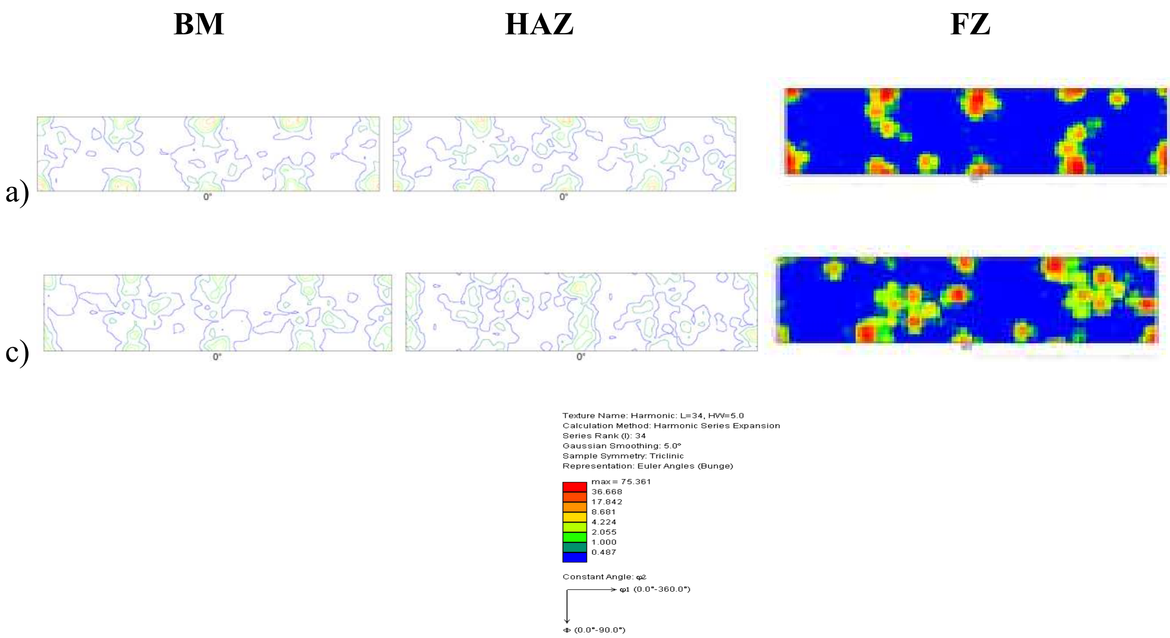

Fig. 5 ODF at different zones of weld joint (BM, HAZ and FZ) of industrial aluminium (a) before and (b) after heat treatment during 4h at 400°C.

Conclusion

From these results we can conclude that a strong cube texture forms in all zones of weld joint of industrial aluminium. The oriented grains that form in fusion zone grew from the base metal. Heat treatment at 400 °C homogenizes the microstructure between the base metal and heat affected zone without any change in texture behavior.

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