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Original Research Article

Fabrication and properties of ZrO_2/AZ31 nanocomposite fillers of gas tungsten arc welding by accumulative roll bonding

Armin Sabetghadam-Isfahani [a], Hasan Zalaghi [b], Saeed Hashempour [c], Mehdi Fattahi [d,*], Sajjad Amirkhanlou [e], Yousef Fattahi [f]

[a] Mechanical Engineering Department, Petroleum University of Technology, Ahwaz, Iran
[b] Young Researchers and Elite Club, Doroud Branch, Islamic Azad University, Doroud, Iran
[c] Technical Inspection Department, Abadan Oil Refinery, Abadan, Iran
[d] Technical Inspection Engineering Department, Petroleum University of Technology, Abadan, Iran
[e] Young Researchers and Elite Club, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[f] Materials Engineering Department, Isfahan University of Technology, Isfahan, Iran

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ABSTRACT

In the present study, a new method for fabricating ZrO_2/AZ31 nanocomposite fillers of gas tungsten arc (GTA) welding was developed by applying accumulative roll bonding (ARB) to the magnesium sheets coated with ZrO_2 nanoparticles. The purpose of ARB was to create a uniform dispersion of ZrO_2 nanoparticles in the fillers and to form a good interfacial bonding between the magnesium matrix and ZrO_2 nanoparticles. After welding, the effect of ZrO_2 nanoparticles on the microstructure and mechanical properties of weld was evaluated. The test results showed that the yield strength of weld was greatly increased when using the nanocomposite fillers. The improvement in the yield strength was attributed to the grain refinement, coefficient of thermal expansion mismatch and Orowan strengthening mechanisms.

1. Introduction

Gas tungsten arc (GTA) welding is an arc welding process that melts and joins base metals by heating them with an arc established between the tip of non-consumable tungsten electrode and the base metals. The weld pool is protected from the air by the inert shielding gases and a filler is fed into the weld pool during welding. The chemical composition of fillers is a key factor that affects the mechanical properties of weld. Nanocomposite fillers as a new class of nanostructured materials have a great potential to be used in a wide variety of industries owing to their excellent mechanical properties. Nanocomposite fillers can be fabricated by several techniques including powder metallurgy and casting. In the most of cases, these techniques are relatively expensive or have some limitations, e.g., porosity in the matrix, weak interfacial bonding between nanoparticles and matrix, agglomeration, non-uniform dispersion and poor wettability of nanoparticles [1–4].

* Corresponding author. Tel.: +98 913 304 5188; fax: +98 631 442 3520.
E-mail address: fattahi.put@gmail.com (M. Fattahi).
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Accumulative roll bonding (ARB) is an effective technique that can overcome the above problems. ARB involves multiple cycles of surface treatment, stacking, rolling and cutting in which nanoparticles are well dispersed in the matrix with a strong interfacial bonding. Several research works have shown that using ARB to manufacture nanoparticle-reinforced metal matrix composites (MMCs) leads to a uniform dispersion of nanoparticles in the matrix [5–9]. Yoo et al. [5] showed that the addition of nanoparticles to the AZ31 magnesium alloy using ARB could considerably improve the dispersion of nanoparticles and increase the mechanical properties of composite. Schmidt et al. [6] applied ARB to fabricate the MMCs and noted that with decreasing reinforcement particle size, grain refinement was accelerated and the tensile strength was increased. Lu et al. [7] investigated the effect of nanoparticles on the bond strength of MMCs prepared by ARB. It was shown that the bond strength could be significantly improved by adding nanoparticles.

The aim of the present study is to evaluate the feasibility of ARB process for fabricating ZrO_2/AZ31 nanocomposite fillers of GTA welding and to investigate the effect of ZrO_2 nanoparticles on the mechanical properties of weld.

2. Experimental procedure

AZ31 magnesium alloy with the dimensions of 300 mm × 200 mm × 2 mm annealed at 673 K and ZrO_2 nanoparticles with an average particle size of 50 nm were used as the raw materials. Table 1 shows the chemical composition of the AZ31 magnesium alloy.

The production process of ZrO_2/AZ31 nanocomposite fillers consists of three steps. A schematic illustration of the manufacturing steps is shown in Fig. 1. In the first step (Fig. 1a), the annealed sheets were degreased in acetone and

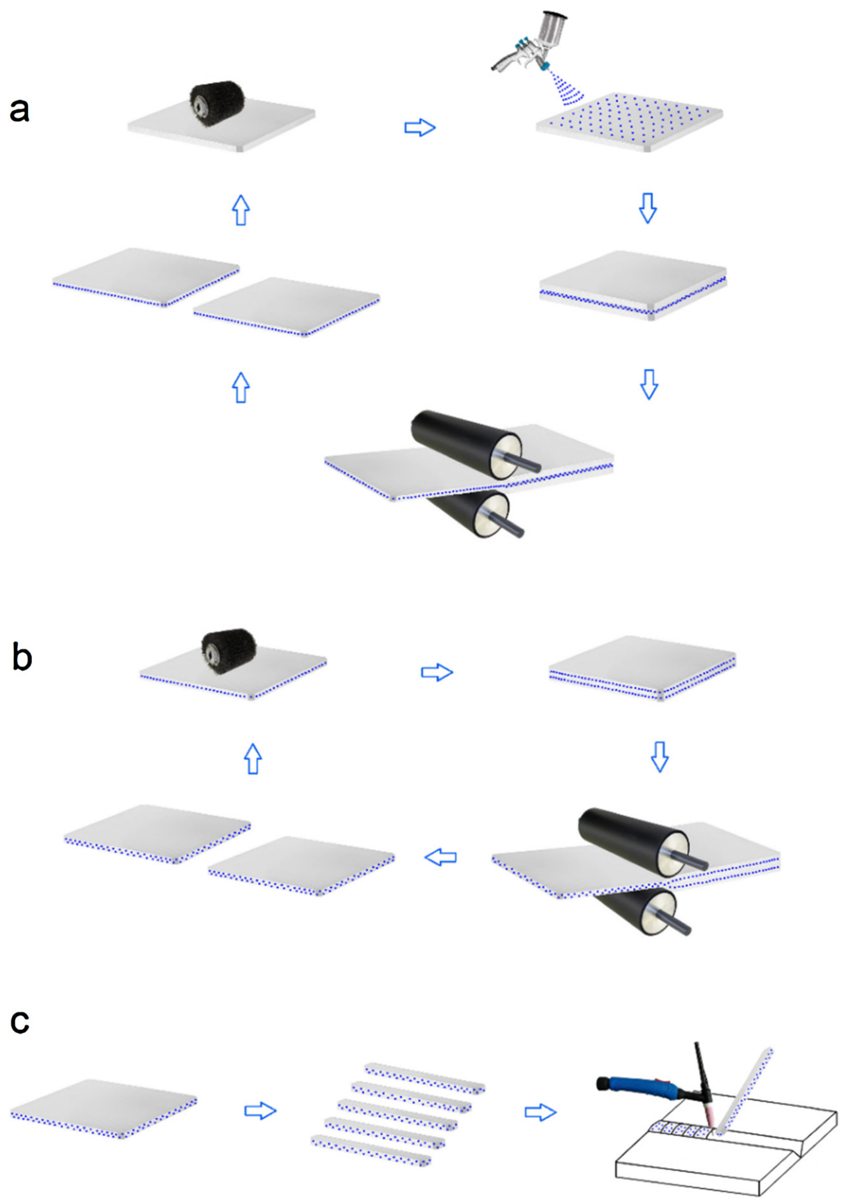

Fig. 1 – Schematic illustration of the production process of the ZrO_2/AZ31 nanocomposite fillers: (a) first step, (b) second step and (c) third step.