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Short Communication

Effect of post-weld heat treatment on the microstructure and plastic deformation behavior of friction stir welded 2024

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ABSTRACT

To improve the plasticity of friction stir welded joints for plastic processing applications, post-weld heat treatment (PWHT) of 2024-O aluminum alloy friction stir welding joints was carried out at annealing temperatures from 250 °C to 450 °C with an interval of 50 °C for 2 h, followed by cooling to 200 °C in the furnace. The effect of PWHT on the microstructure and plastic deformation behavior of the joints was investigated. It was found that the fine-equiaxed grains are stable and retained in the nugget of the joints even after annealing at 450 °C for 2 h. However, the grains in the thermo-mechanically affected zone (TMAZ) of the joints become coarse and equiaxed as annealing temperature increases. The plastic deformation of as-welded joint is very heterogeneous. In contrast, the plastic deformation of PWHT joint is relatively homogeneous by both the nugget and the base material showing large deformation. The decrease in elongation of as-welded joints is completely recovered by PWHT. The high ductility of the joint is mainly attributed to the retention of the fine-equiaxed grains in the nugget during PWHT.

1. Introduction

Due to economical and ecological reasons as well as to improve product properties, aluminum alloy welds, which show high production efficiency and flexibility, have gained more interest in manufacturing lightweight structures for automotives and aircrafts [1–3]. The industrial application of aluminum alloy welds in lightweight constructions is basically connected to one fundamental manufacturing requirement. The formability of welds must be adequate in order to shape the required geometries [4].

It is well known that high-strength aluminum alloys (2XXX series) are widely used for aerospace structures such as fuselage, fins and wings [5]. Unfortunately, such high-strength aluminum alloys are difficult to join by conventional fusion welding due to the occurrence of hot cracking during welding [6]. Friction stir welding (FSW), as a solid state metal joining technique, do prove itself ideal for creating better quality joints compared to fusion welds [6–8]. However, many studies on the transverse tensile properties of FSW joints indicated that the elongations of as-welded joints are only 20–40% those of the BM for the heterogeneous microstructure of the joint [6,9–11].

To improve the mechanical properties of FSW joints, one option is to fully post-weld heat treatment (PWHT) of the welded components. Currently the PWHT mainly consists of solution heat treatment and precipitation or aging treatment, aiming to recover the loss of tensile strength in the nugget zone [12–15]. A few studies on the PWHT of FSW aluminum alloys such as 7449 [14], 6061-O [12], 2219-O [13] and 2024-T4 [15] had shown that the PWHT recovered a large portion of the lost strength in the nugget, but there was an accompanying loss in ductility. The joints have a 40–77% decrease in elongation compared to that of base material (BM). In addition, studies in this area have shown that the fine grains in the nugget are not stable during PWHT, which results in undesirable coarsened grain structures [12–20]. This kind of microstructural instability has been identified as abnormal grain growth (AGG). Although in a few studies AGG has proved to be beneficial to recover the lost strength of joint, it is not at all desirable for enhanced plasticity [17–19]. Ductility falls off sharply due to extreme microstructural instability [18,19]. Accordingly, it is necessary to find out some effective remedial process to improve the elongation of joints, and avoid AGG occurring in the nugget at same time.

Normally the friction stir welds are used in the as-welded condition or with stabilization aging when BM is in the hardened conditions (T3, T4 and T6 tempers). However, there are some advantages in carrying out the welding with BM in a soft condition. The forming operation after FSW can be much more easily performed if the welding is conducted under O condition. Furthermore, the solution and aging heat treatment can restore the mechanical properties of the joints successfully after the forming operation [12–15,20].

The present letter analyzes the microstructure and plastic deformation behavior of FSW aluminum alloys to evaluate if, with the right selection of post-weld annealing treatment parameters, their plasticity and strength could be optimized.

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