Materials and Design 32 (2011) 4825–4831

Contents lists available at ScienceDirect

Materials and Design

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

Improvement of weld temperature distribution and mechanical properties of 7050 aluminum alloy butt joints by submerged friction stir welding

Rui-dong Fu [a,b,*], Zeng-qiang Sun [a], Rui-cheng Sun [a], Ying Li [a], Hui-jie Liu [c], Lei Liu [a]

[a] State Key Laboratory of Metastable Materials Science and Technology, Qinhuangdao 066004, Hebei Province, PR China
[b] College of Materials Science and Engineering, Yanshan University, Qinhuangdao 066004, Hebei Province, PR China
[c] State Key Laboratory of Advanced Welding Production Technology, Harbin 150001, Heihongjiang Province, PR China

ARTICLE INFO

Article history:
Received 29 March 2011
Accepted 13 June 2011
Available online 21 June 2011

Keywords:
A. Non-ferrous metals and alloys
D. Welding
E. Mechanical

ABSTRACT

Submerged friction stir welding (FSW) in cold and hot water, as well as in air, was carried out for 7050 aluminum alloys. The weld thermal cycles and transverse distributions of the microhardness of the weld joints were measured, and their tensile properties were tested. The fracture surfaces of the tensile specimens were observed, and the microstructures at the fracture region were investigated. The results show that the peak temperature during welding in air was up to 380 °C, while the peak temperatures during welding in cold and hot water were about 220 and 300 °C, respectively. The temperature at the retreated side of the joint was higher than that at the advanced side for all weld joints. The distributions of microhardness exhibited a typical "W" shape. The width of the low hardness zone varied with the weld ambient conditions. The minimum hardness zone was located at the heat affected zone (HAZ) of the weld joints. Better tensile properties were achieved for joint welded in hot water, and the strength ratio of the weld joint to the base metal was up to 92%. The tensile fracture position was located at the low hardness zone of the weld joints. The fracture surfaces exhibited a mixture of dimples and quasi-cleavage planes for the joints welded in cold and hot water, and only dimples for the joint welded in air.

1. Introduction

FSW was invented by The Welding Institute in 1991, and has been successfully applied in welding of aluminum alloys, particularly 2XXX or 7XXX series aluminum alloys, which are difficult to weld using traditional melting welding methods [1–3]. However, degradation of the mechanical properties of weld joints of heat treatable strengthening aluminum alloys in the HAZ due to the effects of the welding thermal cycle remains a key issue. Many technical methods have been developed to limit the degradation of joint performance in the HAZ. Submerged welding is considered an effective method of welding, and is employed in various welding processes.

In simple terms, the principle of submerged welding process is that the welds are placed in a liquid medium, and weld processing takes place under a specific ambient temperature. This process is suitable for alloys that are sensitive to overheating during the welding process. Tokisue et al. were the first to use submersion in a rotary friction weld for 6061 aluminum alloys [4]. The results of their study showed that it was possible to generate enough friction for welding even though the samples were submerged. In recent years, some remarkable results were obtained through the use of submerged FSW. Thomas adopted submerged FSW to improve the strength of the FSW joint of 6061 aluminum alloy [5]. Upadhyay and Reynolds investigated thermal boundary conditions and their effects on the mechanical properties of AA7050-T7 FSW joints welded in sub ambient water and a −25 °C liquid medium. The ultimate tensile strength throughout the range of parameters tested showed improvements [6]. Nelson et al. demonstrated that 7075-T7351 aluminum alloys could be considered 'quench sensitive', where the cooling rate from thermal exposure has an important influence on the mechanical properties of the friction stir welds, specifically in the case of natural aging. The addition of cooled water mist behind the FSW tool or a water-cooled anvil resulted in 10% and 8% increase in strength, respectively [7]. Liu et al. found that submerged FSW improved the tensile strength of FSW joints of 2219 aluminum alloy [8]. However, the range of temperature used in the above research was limited below room temperature. There are few reports on FSW under the welding ambient temperature, which is above room temperature.

In the present study, the submerged FSW in cold and hot water for 7050 aluminum alloys is conducted. For comparison, normal FSW in air is also performed. Variations in the weld temperature

* Corresponding author at: State Key Laboratory of Metastable Materials Science and Technology, Qinhuangdao 066004, Hebei Province, PR China.
E-mail address: rdfu@ysu.edu.cn (R.D. Fu).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.06.021