Materials and Design 32 (2011) 1205–1214

Contents lists available at ScienceDirect

Materials and Design

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

Fatigue crack growth resistance of gas tungsten arc, electron beam and friction stir welded joints of AA2219 aluminium alloy

S. Malarvizhi [1], V. Balasubramanian *

Centre for Materials Joining & Research (CEMAJOR), Department of Manufacturing Engineering, Annamalai University, Annamalai Nagar 608 002, India

ARTICLE INFO

Article history:
Received 20 February 2010
Accepted 19 October 2010
Available online 23 October 2010

Keywords:
A. Non-ferrous metals and alloys
D. Welding
E. Fatigue
G. Fractography

ABSTRACT

AA2219 aluminium alloy square butt joints without filler metal addition were fabricated using gas tungsten arc welding (GTAW), electron beam welding (EBW) and friction stir welding (FSW) processes. The effect of three welding processes on fatigue crack growth behaviour is reported in this paper. Transverse tensile properties of the welded joints were evaluated. Microstructure analysis was also carried out using optical and electron microscopes. It was found that the FSW joints are exhibiting superior fatigue crack growth resistance compared to EBW and GTAW joints. This was mainly due to the formation of very fine, dynamically recrystallised grains and uniform distribution of fine precipitates in the weld region.

1. Introduction

Many of the structural components in pressure vessels, transport vehicles, earthmoving equipment, spacecraft, etc. are made of welded joints. The butt welds are the most common ones in the fabrication and construction of many structures. The wide application of butt welds in various structures including offshore, nuclear and spacecraft, gives large scope for the researchers to analyse the behaviour under different types of loading conditions [1]. Failure analysis of the weldments indicated that fatigue alone is to be considered to account for most of the disruptive failures [2]. Even though the fatigue properties of the weld metal is good, problems can be caused when there is an abrupt change in section caused by excess weld reinforcement, undercut, slag inclusion and lack of penetration and nearly 70% of fatigue cracking occurs in the welded joints [3].

AA2219 is basically Al–Cu–Mn ternary alloy with the minor additions of Ti, V and Zr. It has been the main workhorse material for applications at cryogenic temperatures [4]. Though AA2219 has got an edge over its counterparts in terms of weldability, the tensile and fatigue strength of as welded joints are much lower compared to base metal. The joint strength is only about 50% when compared to the base metal strength in T87 condition. The gap between strength values of the base metal and weld metal, particularly yield strength values, is significantly large, forcing the design engineers to use thicker base metal plates, which in turn increases the total weight of the structure. This fact is of concern in aerospace applications because, use of thicker plates due to low yield strength of the weld metal results in lowering of the payload [5].

A useful summary of the four main methods for assessing the fatigue lives of welded joints is contained in the new International Institute of Welding (IIW) fatigue design recommendations [6]. They are: (i) S–N curves for specific welded joints used in conjunction with nominal stresses; (ii) S–N curves for welds used in conjunction with hot spot stresses; (iii) S–N curves for materials used in conjunction with local notch stresses and (iv) the fracture mechanics approach, whereby fatigue crack growth data are used in conjunction with the stress intensity factor to calculate the progress of a known flaw. The first three are intended for application at the design stage and the fourth is not generally used for design but for assessing known or assumed flaws. A fracture mechanics assessment utilizes the same actions as those determined for design calculations. However, fatigue resistance is represented by fatigue crack growth rate data for the material under consideration, expressed in terms of the fracture mechanics stress intensity factor parameter [7].

Kumar and Guha [8] investigated the fatigue characteristics of bead-on-plate gas tungsten arc welded commercial aluminium and AA7020 grade aluminium alloys. They found that fatigue life was drastically reduced in both the alloys due to bead-on-plate welding. Kuk et al. [9] studied the effect of temperature and shielding gas mixture on fatigue life of 5083 aluminium alloy welded by gas metal arc welding process. They found that the fatigue life increased at lower temperatures and decreased at higher shielding

* Corresponding author. Tel.: +91 04144 239734 (O), +91 04144 241147 (R); fax: +91 04144 239734/238275.

E-mail addresses: jeejoo@rediffmail.com (S. Malarvizhi), balasubramanian.v.2784@annamalaiuniversity.ac.in (V. Balasubramanian).

[1] Tel.: +91 04144 239734 (O), +91 04144 329700 (R); fax: +91 04144 239734/238275.

0261-3069/$ - see front matter
doi:10.1016/j.matdes.2010.10.019