Engineering Failure Analysis 18 (2011) 1791–1799

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Characterization of failure modes for different welding processes of AISI/SAE 304 stainless steels

Andrés R. Galvis E *, W. Hormaza

Universidad de los Andes, Cra 1 N° 18A-12 Bogota, Colombia

ARTICLE INFO

Article history:
Available online 28 April 2011

Keywords:
AISI/SAE 304 stainless steel
Arc welding processes
Fatigue
Fractographic analysis
Microstructural characterization

ABSTRACT

Weld joints manufactured with a welding electrode type 308L and by three different arc welding processes shielded metal arc welding (SMAW), gas metal arc welding (GMAW) and flux cored arc welding (FCAW) in a AISI/SAE 304 were studied in order to compare the failure mechanisms associated with their mechanical and microstructural properties. Chemical compositions were analyzed by optical emission spectroscopy and the ferrite numbers (FN) of the welds were also identified. Relevant microstructural characteristics of the different processes were analyzed by microscopy techniques. Finally, fatigue tests were performed to study the variations in the mechanical properties of each process and to analyze their most probable failure modes by means of a fractographic study, in which the characteristic morphologies of each one (nucleation, propagation, final fracture) were identified by means of optical stereoscopy and scanning electron microscopy (SEM). Three different fracture modes were found at the welding joints that showed correlations with microstructural changes produced during the welding process. The first failure mode displayed that the nucleation of the crack was at the weld root. The second failure mode was generated at the heat affected zone (HAZ), where the crack nucleated due to a variation in the grain size produced by the process and then further propagated through the edge of the weld. The third failure mode appeared due to the presence of exogenous inclusions generated by the welding process, which acted as stress concentrators in the weld and produce the initiation and further propagation of the crack. Lastly, some welding processes presented a combination of the previous failure modes and consequently multiple sites of crack nucleation.

1. Introduction

Throughout several years, austenitic stainless steels (ASS) have been employed in industrial applications that range from pipes and pressure vessels to structural purposes. The influences that these materials have on the industry are mainly due to their mechanical strength as well as their excellent corrosion resistance, which can also be attributed to the austenitic phase that appear in the matrix of the material when alloying elements like nickel, manganese, and nitrogen are combined at high quantities [1–4]. Similarly, several methods of joining, like welding, have been broadly performed between these metals because of the low price and high quality of this process. Additionally, for the industrial applications of the AISI/SAE 304 stainless steels, the welding method is widely used due to its simple assembly and/or join on sheets, plates and/or pipes made out of this material. On the other hand, it is also imperative to highlight that during welding many discontinuities are produced, which acts as stress raisers that can lead to a decrease in the life of the weld. Therefore, the problems of this joining method

* Corresponding author. Address: Carrera 76A No. 131-60 torre9 Apt 302, Colombia. Tel.: +57 3153470059.
E-mail address: andresgalvisescobar@gmail.com (A.R. Galvis E).

1350-6307/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engfailanal.2011.04.008