Materials Science & Engineering A 606 (2014) 31–39

Contents lists available at ScienceDirect

Materials Science & Engineering A

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

A comparative study of fatigue behaviour of MAG and laser welded components using reliability analysis

Marco Dourado [a,*], Delfim Soares [a], Joaquim Barbosa [a], António Marques Pinho [a], José Meireles [a], Paula Branco [b], Carlos Ribeiro [c], Carlos Rei [c]

[a] Mechanical Engineering Department, Azurém Campus, 4800-058 Guimarães, Portugal
[b] Instituto de Soldadura e Qualidade, Rua do Mirante, no. 258, 4415-491 Grijó, VNG, Portugal
[c] Sodecia Centro Tecnológico S.A, Rua Engenheiro Frederico Ulrich, 2650, 4470-605 Maia, Portugal

ARTICLE INFO

Article history:
Received 19 January 2014
Received in revised form
18 March 2014
Accepted 20 March 2014
Available online 27 March 2014

Keywords:
Fatigue
Reliability analysis
Weld joint
MIG/MAG
Laser welding

ABSTRACT

Fatigue is one of the main causes of failure of structures and mechanical components, occurring due to the progressive weakening of their strength that reduces significantly their lifetime, when subjected to cyclic stresses over time. In welded components, the joints are the zones most susceptible to crack by fatigue.

Therefore, the base of this study are the Metal Inert Gas/Metal Active Gas (MIG/MAG) and LASER welding manufacturing processes, focused in three main areas involved in an automotive metallic system under dynamic loads: Fatigue testing in order to prevent structural collapse; Heat Affected Zones (HAZ) characterization to evaluate the material properties modification originated by those different technologies; Reliability analysis in order to analyse the performance of the samples and to select the best connection in terms of product life cycle. For this purpose, samples representative of industrial automotive applications (long welds) have been selected to carry out this work. Two types of connected specimens were manufactured, consisting of two steel plates of different thicknesses, overlapping and welded by the MAG process (type A) or the Laser process (type B). Metallographic characterization was performed for both typologies, namely macrostructural and microstructural characterization of the weld joint, and respective HAZ. Mechanical properties were inferred by measuring and mapping microhardness variation on the neighbour of the weld joint. Fatigue tests were carried out for specimens type A and type B, using 15 samples of each type that were tested under 3 levels of stress amplitude. The samples manufactured by the Laser process show better fatigue behaviour when compared to the samples manufactured by MAG welding. The better weld joint solution is proposed in accordance with the reliability analysis of the obtained fatigue test results.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The industry, including automotive, struggles continuously with the need to increase competitiveness and profitability. Due to their structural importance, metallic components and systems represent the major part of the weight of an automobile. These metal components are connected together in order to create multiple subsets, to get the final product. Therefore, several sets of metallic components/systems need to connect together.

Due to specific structural needs, the dynamic requests change all over the metallic components/systems. In addition, the continuous search for lighter and more resistant solutions, with lower costs and reaching the dynamic specifications and quality, with a perfect repeatability of the manufacturing process, force the designers to continuously search for solutions in order to optimize this set of variables. Furthermore, if the metallic components/systems have to respect security's characteristics or are exposed to continuous environmental and mechanic attacks, they will require increased attention. Welding is the most used technological process to connect two components and MAG/MIG, TIG, Submerged Arc and Laser processes are those more commonly used in industrial applications.

It is known that the welded joint of two components is the most susceptible zone to initiate fatigue crack, reducing significantly the component lifetime [1].

Fatigue is the result of regular or irregular cyclic stresses imposed on the component, that may lead to fatigue cracks,

* Corresponding author.
E-mail addresses: mdourado@dem.uminho.pt (M. Dourado), dsoares@dem.uminho.pt (D. Soares), kim@dem.uminho.pt (J. Barbosa), acmpinho@dem.uminho.pt (A. Marques Pinho), meireles@dem.uminho.pt (J. Meireles), pabranco@isq.pt (P. Branco), carlos.ribeiro@ct.sodecia.com (C. Ribeiro), carlos.rei@ct.sodecia.com (C. Rei).

http://dx.doi.org/10.1016/j.msea.2014.03.067
0921-5093/© 2014 Elsevier B.V. All rights reserved.

initially microscopic, that propagate to visible cracks, leading to the rupture of the component [2–4]. Residual tensile stresses along the welded joint imposed by heating and cooling cycles may cause a decrease of the fatigue life of welded components [5]. The weld joint geometry also has an important effect on the fatigue life of the structure. A defective weld geometry may also increase tensions in the welded joint [6–8]. Weld joint geometry depends on the process and the operation parameters, namely the welding energy, welding speed, voltage and electric current, and wire feed speed [9,10]. High welding speed decreases the arc exposure time and does not allow complete base material dilution. Consequently, penetration and the extension of the heat affected zone decrease. In the MAG process, the welding speed and energy are lower than those used on the Laser process. Thus, higher base material dilution, penetration and area of the heat affected zone can be expected [10–12]. However, concentration of residual stresses also increases [13,14]. The Laser process allows higher welding speed, thus shorter exposure time. However, the capacity to employ higher energy and at the same time low heat input, make the process very advantageous to be used in the construction of welded joints subject to fatigue [12].

Fatigue must be considered as a primary factor to take into account in the reliability of any structure or component. Reliability can be defined as the probability of a component or system to perform its function over a period of time, under certain conditions. Reliability engineering studies the components or systems lifetime through modelling and statistical analysis. With the probabilistic distribution of its useful life, it is possible to achieve the survival probability and to optimize the system performance [15]. Thus, it is natural that there is a great need to safely estimate the components and/or mechanical systems lifetime.

This article aims to compare the fatigue behaviour, and consequent reliability, of two components, now denominated by plates, joined by welding using two different technologies – MAG and Laser welding.

As stated above, the fatigue behaviour of the welded joint depends on the characteristics and parameters of the welding process that control the macro- and microstructures of the welded zone. On this study the microstructure of the two specimens is analysed. The macrostructure is analysed via Vickers microhardness and by measuring penetration and area of the heat affected zone. Through macrostructural and microstructural characterization, it is possible to infer the best mechanical behaviour of a specimen type in relation to another.

2. Experimental procedure

In this section it is explained the samples for experimental tests and the experimental procedures are described.

2.1. Starting samples

The specimen manufactured by MAG welding is denominated by type A, and the specimen manufactured by Laser welding is denominated by type B. Two welded sets of each type (A and B) were manufactured. The reliability analysis was applied to both specimens and is presented as a new approach when applied to the comparative study of the two weld typologies manufactured according to the above mentioned welding processes. The welded specimens consisted of two plates of different materials, DD13 and S355 MC, which chemical compositions are presented in Table 1. Plates DD13 and S355 MC were 2.5 and 3 mm thick, respectively.

Table 2 summarizes the characteristics of the 2 weld types. A long weld set (1300 mm) was selected in order to simulate the industrial welding practice, thus increasing the sensitivity of the reliability tests.

Table 1
Chemical composition (wt%) of the material used in welding (supplier data).

Constituents	EN10111 – DD13	EN10149-2 – S355MC
C	0.051	0.050
Mn	0.231	0.240
Si	0.010	0.019
P	0.015	0.012
S	0.011	0.009
Al	0.032	0.025
Nb	–	0
Ti	0.001	0
V	0.000	0
B	0.002	–
Cr	0.022	–

Table 2
Types of specimens of welded joints.

Name of the specimen	Materials	Plates thicknesses [mm]	Welding process
Type A	EN10149-2 – S355MC EN10111 – DD13	3 2.5	MAG
Type B	EN10149-2 – S355MC EN10111 – DD13	3 2.5	Laser

2.2. Samples for fatigue analysis

Samples for fatigue analysis were obtained from two welded sets of each specimen (types A/MAG and B/Laser) with original dimensions $1300 \times 450 \times$ thickness $(t)\,\text{mm}^3$, by sectioning them perpendicular to the weld joint, as shown in Fig. 1a. The sets are identified as “set A1” and “set A2” for specimen type A, and “set B1” and “set B2” for specimen type B.

One must bear in mind that unlike the scheme of the weld joint shown in Fig. 1a, the width of the MAG weld joint was not constant along the entire joint length, which did not happen in the joint obtained by the Laser process. Ten samples were cut from each welded set with dimensions shown in Fig. 1b, i.e. twenty samples of each specimen type (A and B).

2.3. Samples for metallographic analysis

Two samples for metallographic analysis, as shown in Fig. 1c, were collected from each welded set (A1, A2, B1 and B2), one from the central zone of the steel sheets and the other at 50 mm from the end, as shown in Fig. 1a. Total four samples were cut from each specimen type (A and B). The samples were cut perpendicular to the axis of the weld joint with an average width of 20 mm using a lubricated saw to prevent heating of the area to be analysed.

The samples surface were prepared for macrographic and micrographic analyses by traditional polishing techniques. The microstructure was enhanced by chemical attack with Nital 5 reagent.

2.4. Metallographic characterization

Each joint was characterized with respect to its geometry and dimensions through macrostructural analysis according to the following parameters: total area of the weld joint and HAZ of the base material. Microstructural analysis is made in order to evaluate the change in microstructure between the base material and the weld of each specimen. The samples for microstructural analysis are observed at an ampliation of $50\times$ on an electronic

Download English Version:

https://daneshyari.com/en/article/1575030

Download Persian Version:

https://daneshyari.com/article/1575030

Daneshyari.com