Effect of Welding Process on Microstructure and Mechanical Properties of Duplex Stainless Steel Welds

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Abstract: The purpose of this study is a comparison between the effect of two electrical arc welding processes, on the structural and mechanical behavior of 2205 duplex stainless steel weldments, the first one is the manual process GTAW and the second one is the automatic process SAW. This effect has been identified and examined in the different welding area namely, the base metal BM, the heat affected zone HAZ and the weld metal WM, using optical metallographic techniques and mechanical methods by hardness tests.

Keywords: Duplex stainless steel, Welding, Microstructure, Mechanical properties.

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1. Introduction

Welding is an assembly process which aims to create a physical continuity between two metallic elements so that the assembly thus produced meets in all respects the requirements relating to its properties. It is also used for the repair of parts by metal coating (reloading by welding) [1, 2].

A welding process involves a set of parameters that must adapt to each welding job performed. Each welding process has various advantages and disadvantages that determine the choice of the method to be used for given job. Thus, after having identified the correct welding process to be used, there remain several parameters to be determined such as the choice of the filler metal, the current or voltage welding, the type of current and polarity, the choice of a protective gas (if applicable), wire feed speed (if applicable), welding sequence development, and finally welding technique (oscillatory motion, angle of the electrode, etc.).

Gas–tungsten arc welding (GTAW) is a process that melts and joins metals by heating them with an arc established between a non-consumable tungsten electrode and the metals. Submerged arc welding (SAW) is a process that melts and joins metals by heating them with an arc established between a consumable wire electrode and the metals, with the arc being shielded by a molten slag and granular flux [3].

The choice of a material for a given application requires ensuring its durability in its conditions of use, especially environmental, this is particularly true for systems intended to work under welded joints in corrosive atmospheres. For this reason we have to use the chromium-based steels commonly called duplex stainless steels, steels of choice and quality [2].

Duplex stainless steels are widely used in the industry, especially in the chemical industry and in the petrochemical industry.

They combine good corrosion resistance, high mechanical properties and easy implementation. Their physical properties are between those of austenitic stainless steels and those of ferritic stainless steels [4, 5].

2. Materials and methods

The base metal used in this work in the form of pipes, the first one of 2” diameter and 5.54 mm thickness, the second one of 32” diameter and 15.87 mm thickness, the filler metal chosen is ER 2209. The chemical composition of the base metal and the filler metal is given in Table 1. The welding parameters used in this study are listed in Table 2.

Microscopic observations of the samples are executed on cross sections to the welding direction, this last have undergone a polishing cycle to the mirror state, using standard techniques for mechanical polishing. Then the samples are electrolytically etched in 10 N KOH solution at 5V potential for 20 seconds, using an optical microscope (NIKON ECLIPSE LV100ND). To confirm the effect of the welding process on the mechanical properties, hardness measures (HV$_{10}$) are taken across the welds joint using a durometer type INNOVATEST MEMESIS 9000 (Fig. 1), according to three profiles P1, P2 and P3 as illustrated in Fig.2.
3. Results and discussions

3.1 Microstructure

Fig.3 shows the micrograph of the base metal consisted of two-phase banded microstructure, where the elongated austenite (γ) phase is elongated in the ferrite matrix (δ) along the rolling direction without any precipitates.

The microstructure of the weld metal shows in the Fig.4a produced by the GTAW process shows a solidification structure characterized by coarse ferrite grains, in which austenite appears under different morphologies: grain boundary allotriomorphs (GBA) at the prior ferrite/ferrite grain boundaries, widmanstätten austenite (WA) and in the last the intragranular austenite (IGA) [6, 7].

On the other hand the microstructure of the SAW weld metal (Fig.4b) is characterized by low ferrite content and coarse austenite morphology, this is due to the low cooling rate induced by the high heat input of welding process.

The heat affected zone HAZ is located between the weld metal and base metal, just after the melting line, the reached temperature is almost 1450 °C (Fig.5), we can clearly see the big difference between the two heats affected zone, a small HAZ for the first weldment GTAW about 150 µm and little amount of fine grains austenitic. On the other hand for the second weldment SAW, characterized by a large HAZ average 300 µm with increase of the austenite content and becomes coarse, due to the great thermal effect induced by the SAW process and low cooling rate [8].
3.2 Hardness

The hardness evolution in the two welds is shown in Fig. 6. A stable hardness of about 258 HV is observed for the base metal, induced by the austenitic-ferritic structure. For the HAZ we note that, a remarkable increase in hardness for the first and second coarse-induced welding due to the solidification mode and cooling conditions. The hardness of the deposited metals is lower than that of the base metal and HAZ, particularly the second weld metal, due to the low ferrite content and coarse austenite grains [9].
Fig. 6 Hardness profiles across the two weldments

4. Conclusions

The microstructure of the weld metal for both welding processes reveals three different forms of the austenitic phase: allotriomorphic at grain boundaries GBa, widmanstätten side-plates WA and intragranular austenite particles IGA;

The high energy of the SAW welding process and consequently the low cooling rate promotes low ferrite content, coarse austenite morphology and wide heat affected zone HAZ;

The hardness is a function of several parameters among which can be mentioned: the size of the grains, phase volume fraction and the welding thermal effect.

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References