PROCESS PARAMETERS AND THE STRUCTURE OF MAG PULSED DUPLEX STAINLESS STEEL WELDED JOINTS

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Abstract

The paper sets out a synergic program by MAG pulsed welding of Duplex stainless steel plates with thickness of 12 mm. The selected filler material was a E2209-16 wire with a diameter of 1.2 mm and as shielding gas Cronigon 2 was used.

The root layer was obtained at lower linear energy, of 6.9 kJ/cm, and for the filling layers the heat input was different namely: 10 kJ/cm, 15 kJ/cm and 20.7 kJ/cm. Macro- and micrographic analysis showed that variation of linear energy for obtaining the filling layers, by reducing the welding speed or increasing the welding current, permitted the obtaining of welded joints without continuous metallic defects and of a free defects surface such as marginal notches.

Keywords: MAG pulsed welding, structure, duplex stainless steel

1. INTRODUCTION

The synergic MAG welding process in pulsed current or in impulses is characterized by the coordinated transfer of the metal drop through the electric arc as a result of the periodical modification of the welding current.

The essential advantage of this process is related to provide the transfer without short circuit (by spraying) of the melted metal in the entire work domain and thus in the domains corresponding to the transfer by short circuit, intermediary transfer respectively, characterized by the instability of the welding process and by intense spluttering. At the same time, it allows the energy control introduced in the components by smaller values as compared to welding by spraying (which is often compared to), having the effect on reducing the stresses and welding distortions.

Duplex stainless steels are biphasic material that has under delivery conditions approx. 50 % ferrite and 50 % austenite [1, 2], which is why they are also known as ferrite-austenite or austenite-ferrite stainless steels. They combine the good properties of ferritic stainless steels and of austenitic stainless steel. In simple terms it can be said that the ferrite provides the mechanical and stress corrosion resistance while austenite offers the tenacity; the two of them lead to obtaining of a steel with biphasic microstructure and a yield strength limit at least double than that of AISI 316 L steel [1].

The biggest part of industrial constructions demands to welding techniques. Although the idea that they have good welding ability is accepted, the melting and solidification processes appeared during welding worsen their favourable microstructure. [2, 4-6].

This paper aims to capitalize the advantages of pulsed current synergic welding and to optimize the process parameters so that the welded joint and heat affected zone microstructure to have a reduced quantity of fragile precipitates (nitrides Cr_2N, carbides $M_{23}C_6$, σ phase, etc.) and the volume fraction of ferrite should not exceed the maximum of 70 % admitted limit [3, 7].

2. EXPERIMENTAL PROCEDURE. ESTABLISHING THE SYNERGIC WELDING PROGRAM

The working program was conducted on a modern welding source with inverter, LUC 500, built in a modular system, programmable with a Siemens microprocessor and having the possibility to be connected to a PC.

Initial welding conditions:

- definition of the jointing: **homogenous**

  a. **base metal**

  - Duplex stainless steel plates s = 12 mm ;
  - type of welded joint: butt welding;
  - thickness of welded joint: 12 mm
  - welding position: horizontal PA;
  - welding technique: MAG pulsed current;
  - filler material: E 2209-16 wire (AWS A5.4)
  - electrode wire diameter: d_s = 1.2 mm;
  - shielding gas: Cronigon 2 (97.5 % Ar + 2,5 % CO_2), Linde;
  - gas flow: 18 l / min.;
  - welding direction: to the left;
  - angle of the electrode wire: 85°;

Figure 1 shows the position of the components to be welded.

Figure 1 Position of the components to be welded

For these conditions there were 3 sets of samples welded with different linear energies, and in each case 2 different welding technologies were used i.e. one technology for the root layer and another technology for the filling layers. Further it is presented the execution stages of the 3 welded joints with the 3 linear energy values: 10 kJ / cm, 15 kJ / cm and 20.7 kJ / cm. The root layer was realized at a lower linear energy, of 6.9 kJ / cm, in order to avoid the root penetration and leakage of the melted metal.

Sample set 1:

- the welding was carried out in 4 passes, 1 root pass and 3 filling passes with the following welding technological parameters:

a - root layer: the wire feed speed 5 m/min.; the average welding current 116 A; the electric arc voltage 20 V; the welding speed 20 cm / min; the linear energy 6.9 kJ / cm;

Furthermore, establishing of the welding parameters in synergic systems is carried out by proper selection of the electrode wire feed speed the v_{as} = 5 m / min.

Using this wire feed speed a voltage pulse of 28 V and the following pulse current parameters values resulted: pulse current I_p = 328 A, pulse time t_p = 2 ms, base current, I_b = 56A, pulse frequency f = 146 Hz.

b - filling layers

The filling layer was obtained in 3 passes with a linear energy of 10kJ/cm and the following average values of the welding technological parameters: the wire feed speed 8 m/min., the welding current 180 A; the arc voltage 28 V, the voltage correction +3 V; the welding speed 30 cm / min. and the linear energy 10 kJ / cm.

The values of the pulsed current parameters corresponding to the 8m/min wire feed speed using the established welding conditions are the following: pulse current, I_p = 328 A; pulse time t_p = 2 ms; base current I_b = 96 A, frequency f_p = 236 Hz.

By analysing the pulsed current parameters mentioned above for the 2 wire feed speeds of 5 m / min for the root layer and 8 m / min for the filling layers, the following can be noticed:

- pulse current and the pulse time respectively remain unchanged when the electrode wire feed speed is modified in order to obtain the same conditions of melting - formation and falling of the metal drop from the wire top;
- modification of the feed speed causes the obvious modification of the pulse frequency, almost doubling its value, being determined by the condition that the volume and respectively the diameter of the metal drop formed at the wire top remain almost steady this is one of the conditions for keeping the synergy in pulsed welding;
- increasing the wire feed speed causes a slight increase almost linear, of the base current in order to obtain the wire melting conditions and for providing the electric arc stability respectively. The aspect of the welded joint surface is shown in **Figure 2**.

It can be noticed that there are no surface defects such as cracks, pores and marginal notches, there is good moistening of depositions to the base metal. Correct positioning of the electrode wire in the groove when carrying out the 2 passes is shown by corresponding super elevation, the absence of marginal notches respectively the uniformity of the 2 passes without the appearance of a surface with notches in the bounding area between them.

Figure 2 The aspect of the exterior surface of the welded joint E_l = 10 kJ / cm

One also notices that the last layer was obtained in 2 passes considering the high welding speed used which makes it difficult to fill the filling layer in 1 pass; this being caused by keeping the linear energy steady for all the passes.

The second set of samples was carried out in similar conditions regarding the pulsed welding technological parameters and for modifying the linear energy for the filling layer an increase of the linear energy from 10 kJ / cm to 15 kJ / cm was obtained.

The welding was made in 3 passes, 1 root pass and 2 filling passes with the following technological welding parameters:

a - root layer: the wire feed speed 5 m / min, the average welding current 116 A, the electric arc voltage 20 V, the welding speed 20 cm/min, the linear energy 6.9 kJ / cm;

For these values the following pulsed current parameters were obtained: the pulse current I_p = 328 A, the pulse time t_p = 2 ms, the base current I_b = 56 A, the pulse frequency f =146 Hz.

b - filling layers

The layer filling was carried out in 2 passes, keeping the same welding parameters and respectively a 15 kJ / cm linear energy.

The average values of the technological welding parameters used for the filling layers are the following: the wire feed speed 8 m / min, the welding current 180 A, the arc voltage 28 V, the voltage correction +3 V, the welding speed 20 cm / min, linear energy 15 kJ / cm.

The exterior surface of the welding is shown in **Figure 3**. It can be seen that there are no surface defects such as cracks, pores and marginal notches, there is also a good moistening of the depositions to the base metal. Correct positioning of the electrode wire in the filling layer when carrying out the last pass is emphasized by suitable super elevation and absence of marginal notches.

Figure 3 Exterior surface of the welding E_l = 15 kJ/cm

Figure 4 Image of the exterior surface of the welding E_l = 20.7 kJ/cm

One can also notice that the last layer was realised in one pass taking into consideration the lower welding speed used which makes the filling layer possible on condition that the linear energy for both passes remains steady.

For the third set of samples, increasing of the linear energy was done by growing the welding current from 180 to 230 A. As a consequence, the linear energy increased to approx. 20.7 kJ. The root layer was obtained in similar conditions as the previous cases. Similar to the previous case, the filling layer was carried out in a number of 2 passes keeping the welding parameters unchanged respectively the linear energy of 20.7 kJ / cm. The average values of the technological welding parameters used for the filling passes are the following: the wire feed speed 9.5 m/min, the welding current 230 A, the arc voltage 30 V, the voltage correction +3 V, the welding speed 20 cm / min, linear energy 20.7 kJ / cm.

The following pulsed current parameters corresponding to these values were obtained: the pulse current I_p = 328 A, pulse time t_p = 2 ms, base current I_b = 132 A, pulse frequency f = 280 Hz. The exterior surface of the welding obtained using these technological parameters does not have continuity metallic defects (**Figure 4**), and has good moistening of the depositions to the base metal.

Figures 5 and **6** show the dendritic microstructure of the welding and its interface with the base metal (**Figure 6**) both images proving that the established technological program is the appropriate one.

Figure 5 Microstructure of the welding obtained with E_l = 15 kJ / cm

Figure 6 Microstructure of the weld-heat affected zone interface for E_l = 15 kJ / cm

3. CONCLUSIONS

For the used experimental conditions, the execution of the root layer requires a 6.9 kJ / cm lower linear energy, which avoids the penetration and leakage of the melted metal.

The establishing of the welding parameters in a synergic program can be carried out either by proper selection of the electrode wire feed speed or of the welding current, the imposed condition being that the volume and the diameter of the metal drop formed at the wire top remains approximately steady; this condition represents one of the requirements for keeping the synergy in the pulsed welding.

The modification of the linear energy within the limits 10...20.7 kJ / cm provides the obtaining of welded joints with the suitable geometry, without surface defects and with a microstructure consisting of mainly austenite and ferrite in proportions favourable for exploitation conditions with no risks of premature breakage.

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