MICROSTRUCTURE EVALUATION OF STAINLESS STEEL WELDS

Ionuţ Claudiu ROATĂ, Elena Manuela STANCIU, Alexandru PASCU
Transilvania University of Brasov, Romania

Abstract. This study aims to determine the optimal parameters for cold metal transfer MAG welding of stainless steel. Starting from this perspective, the filler material of ER 316LSi full wire type and a MAG CMT - Pulse regime of welding with a low linear energy were used. Welded joints characterization was acquired by performing macro – microscopic analyses, mechanical tests (microhardness) with the purpose of lowering the thermo - mechanically affected zone. The results focus on the significant influence of the welding parameters over the weld bead geometry. The results shows that by using a proper welding speed is possible to reduce the microhardness of the weld bead and to obtain a high quality welded joint.

Keywords: stainless steel, cold metal transfer, filler material (ER 316LSi), microhardness

1. Introduction

Investigations regarding the stainless steel welding indicate that in order to obtain a high quality of the welded joint is necessary to minimise the heat input during the welding process [1]. In this moment one of the most suitable methods for joining stainless steel material is by laser welding. Beside the laser technology, the MIG CMT (cold metal transfer) is a technique witch can provide good results for stainless steel welding.

As previously described in [2, 3, 4], Cold Metal Transfer (or CMT) is an adapted short - circuit MIG/MAG welding technique that employ a fast power regulation together with quivering movement of the wire electrode. The wire electrode motion is particular to CMT process because it does not just supplies into the workpiece but it drawn as well, this wire retreat attends the material transfer from the electrode to the weld and generally it is 30 % less heat input in correlation with the average MIG methods.

The CMT welding process is successfully used for welding of similar or dissimilar materials. In a recent study Liu [5] has obtain good results for cold metal transfer welding of aluminium alloys and stainless steel. R. Cao [6] uses the same technique for welding-brazing titanium to cooper. A good tensile behaviour was obtained in this case using ER CuNiAl copper wire as filler metal.

Welding of aluminium to mild steel is another possible application of cold metal transfer welding process. In [7] is showed that is feasible to weld 1 mm aluminium alloy to 1 mm thick mild steel (Q235). By using CMT the heat input was limited at 100-200 J/mm and the heat affected zone was well controlled.

Even so the stainless steel has a good overhaul weldability several down backs can occur in case of welding thin sheets (< 1.5 mm). In this case the parameters must be optimised in order to avoid the deformation of the components. The most common stainless steel used for different applications is the AISI 304 grade. The usual chemical composition is 18% Cr, 8% Ni with a carbon content of 0.1% (at the present time, the carbon content was significantly reduced). Even so, the AISI 304 is an austenitic stainless steel, it solidifies initially as delta ferrite, which has a high solubility for sulphur. As a result, the steel may contain traces of residual delta ferrite (up to 13%) [8]. For this reason is very important to limit the heat input used during the welding process. The lowered heat of the CMT procedures allows to be applied to thin sheet materials on which the prior MIG welding was not achievable [3].

In this study is attended the MIG CMT welding of 1.5 mm thick AISI 304 stainless steel plates. By using the cold metal transfer process is desired to avoid the occurrence of the Cr precipitations of the grain boundaries in the weld bead.

2. Experimental frame

For the experimental tests, 304 stainless steel thin sheets were used (100×70×1.5 mm) and their chemical composition is presented in Table 1. For the welded joints, ER 316LSi with a 1.2 mm diameter was chosen as filler material, whose chemical composition is presented in Table 2.

For the achievement of experimental tests, the TransPulsSynergic 3200CMT welding source was chosen and the welding parameters such as: welding current, voltage, wire feed speed and welding speed is presented in Table 3. As show in Figure 1 the welding torch was manipulated by a welding tractor.

For welded joints testing, samples were taken – off on the crosswise direction of the welded joints, according to EN ISO 15614-1:2003, for the macro – microscopical analyses and microhardness.

Table 1. Stainless steel 304 base material chemical composition

Cr [%]	Ni [%]	Mn [%]	Si [%]	Mo [%]	Cu [%]	C [%]	S [%]
20	10.5	2	1	1	1	0.15	0.04

Table 2. Filler material (ER 316LSi) chemical composition

Cr [%]	Ni [%]	Mn [%]	Si [%]	Mo [%]	Cu [%]	C [%]	S [%]
18-20	11-14	1-2.5	0.65-1	2-3	0.75	0.03	0.03

Table 3. Welding parameters

Sample code	Welding current [A]	Welding voltage [V]	Wire feed speed [m/min]	Welding speed [mm/min]	Frequency [Hz]
P1	70	16.9	2.2	800	4
P2				1000	
P3				1200	
P4				1400	

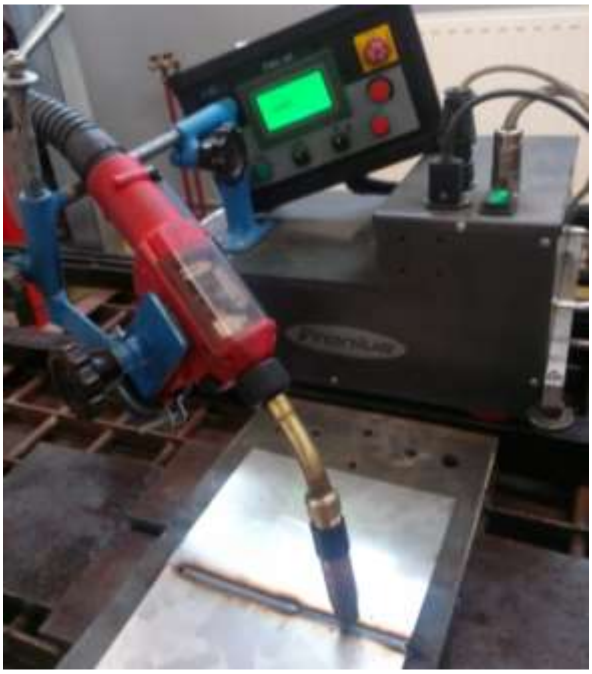

Figure 1. Experimental frame used for the stainless steel welding

The optical analyses of the welded joints (SR EN 1321:2000), was realized by using a Nikon metallographic microscope model Eclipse MA 1.

The samples were coarse cut and then grinded with sandpaper with a grain between 1000 and 2500, the polishing being performed on felt and aluminium suspension of 5 µm. The samples were prepared by means of electrochemical etching in 10% solution of Oxalic acid. The results are in accordance with the data stated before, and in order to sustain this fact, some metallographic analyses were accomplished in the contact zone between the base material and the welded bead (figures 2 … 5). The studies carried out so far show that Fe content in weld metal along with Cr and Ni contents may determine the solidification range and dependence on the composition. The increase of the iron amount in a regular Cr/Ni ratio leads to a limitation of ferrite and austenite area. Any alloy that hardens as ferrite form, usually it's either fully ferritic or made of a ferrite and austenite composite at the end of hardening path. Primary hardening of austenitic steels can be developed as either austenite or ferrite. If the Cr/Ni ratios are increased, the primary hardening process emerges as δ-ferrite (FA solidification type) while at decreased ratios it develops as austenite (AF solidification type). Specimens of various grain sizes were employed in order to define the microstructures during distortion process. For 304 Ni stainless steels, the converting microstructures are made of mechanical twins, namely, α-martensite. The volume fraction of the α-martensite develops with raising strain in 304 stainless steels for a certain grain extent. The content of α phase extends with a reduction in grain size at 304 stainless steel. The strain- solidification demeanor displayed by the stainless steels employed reveals the role of α-martensite and grain size increase in the case of 304stainless steels. The achievement of δ-ferrite advances the development of a chromium decreased zone damaging the austenitic demeanor.

The microhardness tests were achieved on FM 700 type of microhardness tester, by performing three tests of HV_{01} for each zone separately (ISO 9015-1) as seen in figure 7.

Increasing the welding speed influences the mechanical proprieties by lowering the microhardness from 212 HV_{01} (P1) to 192 HV_{01} (P4) in weld bead and from 204 HV_{01} (P1) to 184 HV_{01} (P4) in heat affected zone (figure 6).

Figure 2. Metallographic structures of P1 sample

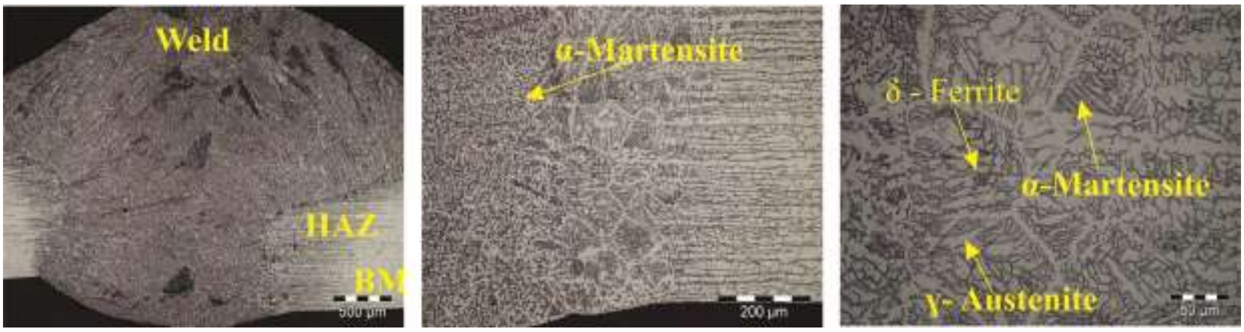

Figure 3. Metallographic structures of P2 sample

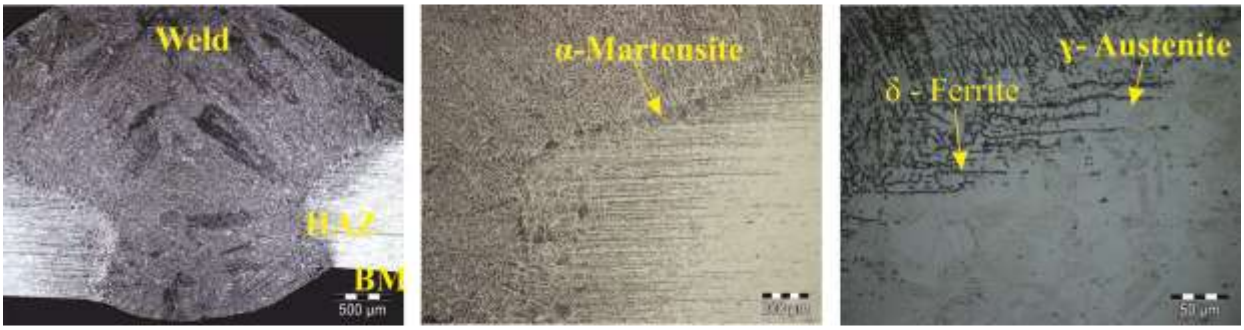

Figure 4. Metallographic structures of P3 sample

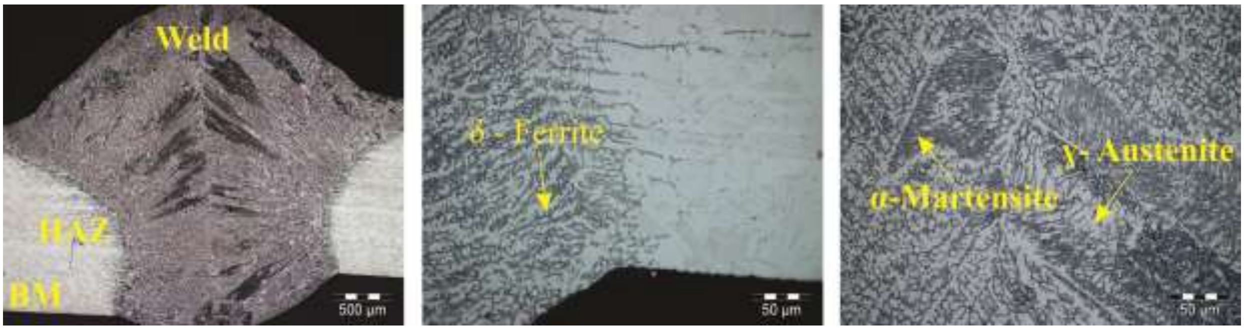

Figure 5. Metallographic structures of P4 sample

4. Conclusions

The present study was focused on the welding speed influence on the microhardness weld bead and heat affected zone (HAZ).

By increasing the welding speed, the microhardness in welded bead and HAZ decreases.

Therefore a relation between the linear energy and the hardness is formed, as the principal effect of the welding speed is the direct dependence with the linear energy induced in the welding process.

Optimal welding speed was determined to be between 800 and 1200 mm/min at a welding current of 70 A and 2.2 m/min wire speed.

The presented aspects indicate the fact that the optimal welding speed is conditioned by microhardness.

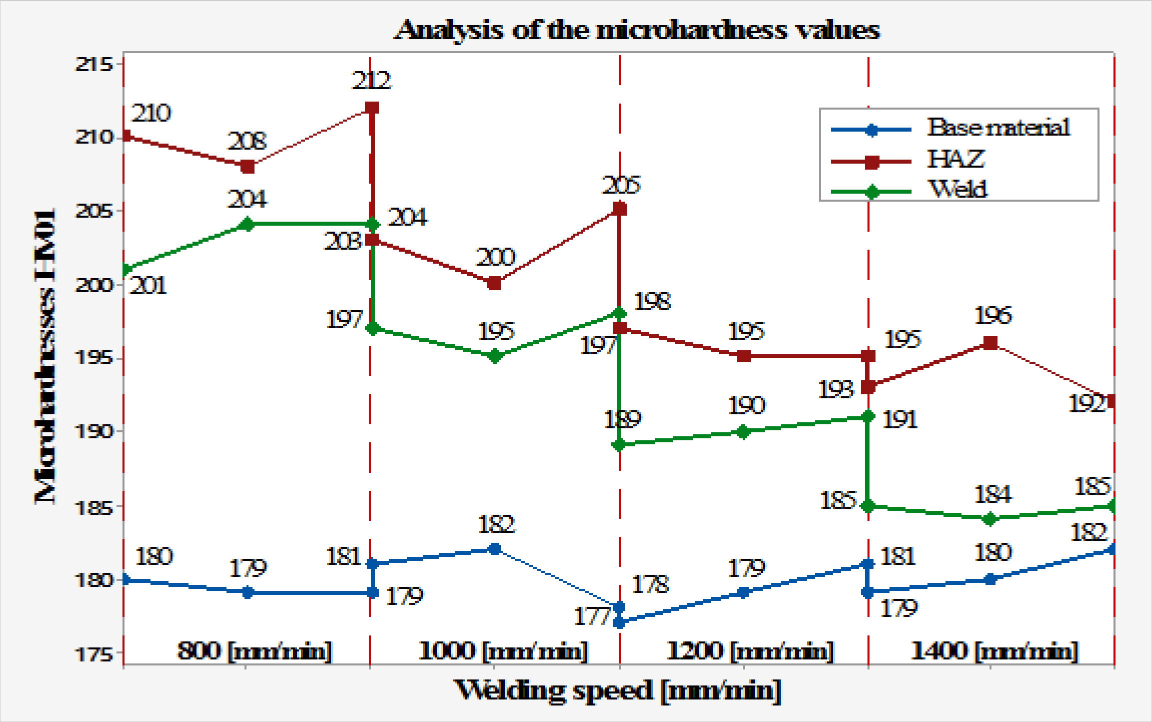

Figure 6. Graphical representation of the microhardness analysis

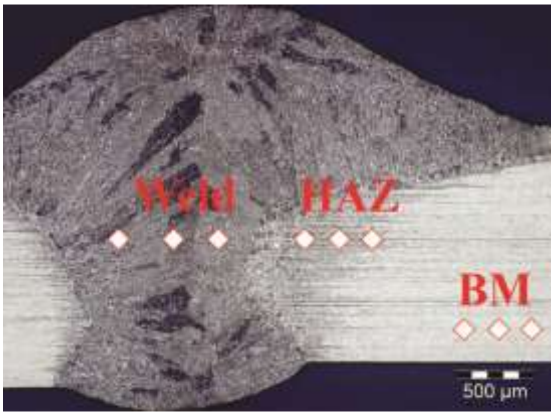

Figure 7. Arrangement of microhardnesses indentations

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