INFLUENCE OF SHIELDING GAS MIXTURES ON WELDING PROCESS OF GALVANIZED SHEET

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Abstract. *An investigation into the use of variable mixture of gas with standard weld brazing filler metals was conducted to determine the potential of the MIG-brazing welding process.* The base metal investigated was a fine galvanized sheet with 0,8 mm of thickness. *The fillet welded joints were made using a stationary, straight machine welding gun with constant speed. The filler material was cooper-based brazing combined with 3 shielding gas mixtures that were 100% Argon, Argon + 2%CO_2 and ternary mixture Argon- O_2- -H_2,, used to evaluate shielding gas influence on the welding process. The evaluation of the welded joints was made by tensile tests, accelerated corrosion tests, besides its microstructural analysis through optic and scanning electron microscopy. The results show hat ternary mixture was better than the other shielding mixtures due to the covering zinc layer preservation at accelerated corrosion test. The all joints exhibit excellent joint geometry without notches, and are free of cracks and pores.*

Keywords: *MIG brazing, Galvanized sheet, accelerated corrosion test*

1. Introduction

Surface-coated sheet metal has been increasingly used in many industrial sectors because of developments in sheet metal production and stringent requirements on corrosion protection. Depending on the production process being used, the zinc layer applied to the base metal is between 1 and 20 μm of thickness, Bouaifi (2003).

Towsend and Bhadha (1990) reported that Zinc is an effective way of protecting steel against corrosion. This protection results not only from the barrier effect of the cover layer but also – and more importantly –from the cathodic protection afforded by the zinc layer when damage occurs.

The preparation needs for galvanized semis to DIN 50976 are complicated and cost-intensive. For this reason it tends to use bolted or forced-in joints, i.e. methods without any thermal influence.

Bouaifi (2003) shows that the vaporization of protective coating presents considerable problems with beam and gas metal arc welding methods. Undesirable effects that occur during processes include formation of pores in the weld metal, pronounced spattering, generations of fumes and dust, and, in some cases, nonuniform weld shape.

A protective coating must subsequently be reapplied in order to avoid impairment of corrosion resistance.

According to Gärtner (1999), although weld processes fulfil this requirement, they destroy the zinc layer. If is not feasible to carry out partial re-galvanization, the welding is not an alternative either. However, studies and trials have shown that the MIG-Brazing process offered a solution that meets the requirements here

Process principle MIG brazing requires inverter power sources with a special characteristic. A wire composed largely of cooper serves as filler metal here. It is the filler metal, which is responsible for the critical difference from conventional gas metal arc welding (GMAW). Owing to the low fusion temperature of the filler metal no fusion of the base metal takes place in MIG brazing. The 1500 °C fusion temperature of the base metal, steel, is not reached, Fronius Magazine (2000).

When it comes to joining galvanized sheets, the advantages of MIG brazing over others process are readily apparent Fronius Magazine (2001):

- It is a “benign” process with higher process dependability
- The brazed seams are of high quality, in terms of both gap bridgeability and corrosion resistance

•The joint strength is very high – the seam material if of higher strength than the material being joined.

An investigation into the use of variable mixture of gas with standard weld brazing filler metals was conducted to determine the potential of this process for further. The evaluation of the welded joints was made by tensile tests, accelerated corrosion tests, besides its microstructural analysis through optic and scanning electron microscopy.

2. Experimental Procedures

2.1. Material

The base metal investigated was a fine galvanized sheet with 0,8 mm of thickness with specific mass of 91g of Zn/m2, corresponding the covering designation Z 100 according to the standard NBR 7008/03, and the chemical analysis is given on table 1. This type of galvanized sheet is used by many industries, including automotive.

Table 1. Chemical Composition (%) specified for substratum.

	C	Mn	P	S	Al	Si	Nb	Ti	N_2
Chemical Composition	0,0010 a 0,01	0,120 a 0,30	0,010 a 0,02	0,0050 a 0,02	0,0370 a 0,01	0,070 max.	0,022 max.	0,032 max.	0,0025 max.

The fillet welded joints were made using a stationary, straight machine welding gun with constant speed. The filler material was cooper-based brazing (BT511- table 2) combined with 3 shielding gas mixtures that were 100% Argon, Ar + 2%CO_2 and ternary mixture Ar- O_{2}- -H_2, used to evaluate shielding gas influence on the MIG brazing process.

Table 2. Chemical Composition of filler material.

Alloy	Composition (%)						Fusion interval (ºC)	Service Temperature (ºC)
BT	Cu	Zn	Sn	Fe	Mn	Si	-	-
511	97	0.0	0.2	0.2	0.8	1.3	950 – 1050	1050

A data acquisition system was used to determine the electrical waveform characteristics. Voltage was measured between the contact tip and the work. These points were considered as close as possible to the arc possible and best represent the arc voltage. Current was measured using a tachometer. The system gave waveforms of voltage and current versus Time, as well as statistical histograms of voltage, current, and short circuiting time. The low-current-level background period primarily maintains the arc, while the high-current-level pulse forms and transfers one or more small drops from the electrode to the weld pool. This pulsing waveform produces the less desirable globular transfer.

The parameters obtained on welding process were in table 3 .

Table 3.Welding Parameters used for shielding gas mixtures conditions.

Condition	Ar- O_{2-}-H_2	100% Argon	Ar + 2%CO_2
Heat Input (KJ/cm)	4516	4109	4552
Tension (V)	13,8	13,4	13,9
Current (A)	68	82	70

2.2. Tensile Tests

Tensile tests were taken from the weld tests that represented the maximum productivity for each process combination. The tensile tests were made according to ASTM E8 and were carried out at room temperature. Specimens were taken transverse to centerline of the weld for all shielding mixture conditions.

2.3. Metallographic Techniques

Microstructural characterization by optical and scanning electronic microscopy (OM and SEM) including analysis was undertaken for the base metal and weld metal, etched with Nital 2% solution for base metal and ferric chloride 5% for weld metal.

The zinc surface was studied by EDX scanning line analyses SEM.

2.4. Accelerated Corrosion Test

Specimens test were analyzed at all shielding gas mixture with accelerated corrosion test at saline mist chamber for 24 h.

3. Experimental Results

All joints exhibit excellent joint geometry without notches, and are free of cracks and pores. With appropriate parameter values, consistent quality can be achieved over the entire length of the joint. The joint is smooth, uniform, very narrow, and continuous – feature due to the stability of the process, Joseph (2002) .

Another indication of weld quality was found in the macro photographs of the weld cross sections. Figure 1 shows a cross section of the filler welded joint that was obtained.

Significant melting of both the top plate and the bottom plate occurred, resulting in a base metal high dilution of the weld. Brazing filler penetrates deeply into the root opening through capillary action. The previous studies by Bouaifi (2003) showed that this behavior depends on chemical composition of weld metal and parameters used.

The shape of fillet is very important, and convex is the desired shape. When the fillet is convex, the edges of the fillets tend to feather out each edge and blend in nicely with the base metal (fig. 1), Kay (2003).

This indicates three things: there is good metallurgical compatibility between brazing filler metal (BFM) and metal base, the base metal surfaces are clean, and the brazing "atmosphere" is good.

Microstructural analysis showed that polygonal ferrite was the predominant constituent in base metal for all conditions studied. Microstructural evidence of change is clear in HAZ (heat affected zone), with grain of polygonal ferrite size increase (figure 2 A). From Metallographic examination, using ferric chloride 5%, it can be seen from figure 2B, was the dendritic structure in weld metal. When the zinc coating on a steel sheet solidifies, dendrite-type crystals form and grow around a core of solidified Zn. In some cases, this result in a flower-shaped pattern called "spangle" on the surface of the galvanized sheet. Depending on the use, this flower pat-tern is considered desirable in some applications, such as building materials, where it contributes to the beauty of the material surface, Abotani (2003).

Details about the general aspects of fillet welded joint were in figure 3 A and top view (figure 3B). The convexity angle α (figure 3 A) is very important and have correlation with capillary action. The maximum value detected of convexity angle was 131° (ternary condition).

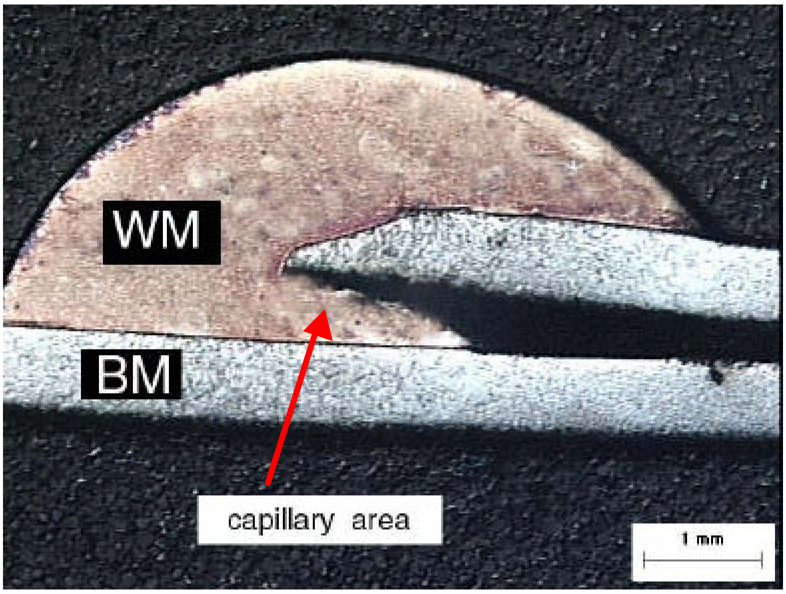
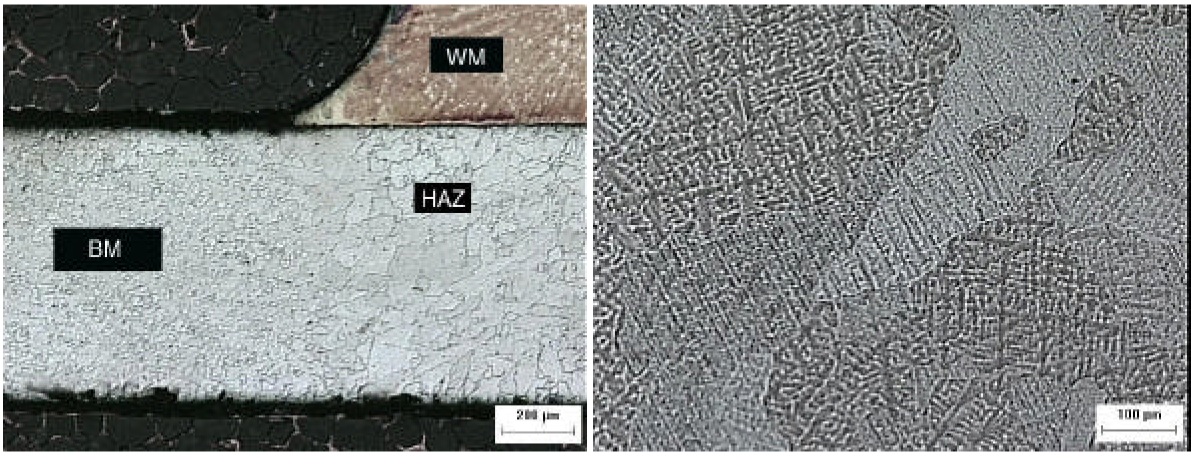
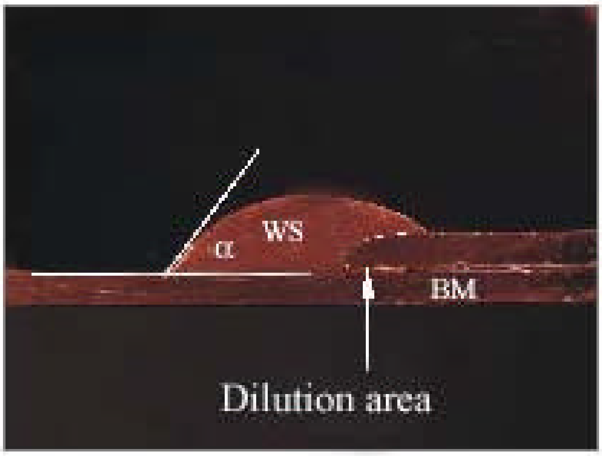


Figure 1. Detail of fillet welded joint obtained by MIG-Brazing welding process showed a high base metal dilution of the weld through capillary. Weld metal (WM) and base metal (BM).



A **B**

Figure 2. A) Optical Photomicrography of base metal (BM) and heat affected zone (HAZ), etched Nital 2%, shows grain size increased at HAZ. B) Detail of dendritic structure at weld metal, etched ferric chloride 5% .



A **B**

Figure 3. A) Details of fillet welded joint shows weld metal, base metal, convexity angle (α) and dilution area. B) Detail of top view of filet welded joint

The specimens tensile tests failed in the base metal to all shielding mixture condition. Figure 4 shows tensile as it failed. Given the ductile nature of the cooper-based weld metal and the fact the weld goes through shear and tensile loading, it is assumed the weld properties were satisfactory (table 4). The analysis of strength of a brazed joint comes from a number of factors, Kay(2003):

- Design of parts being brazed, particularly the design of the outside edges of the brazed joint as far as stress concentration factors are concerned.
- The differential expansion characteristics of the two materials are being joined .
- Compatibility of BFM and the base materials.

Figure 4. Detail of specimen failed in the base metal after tensile test.

Table 4. Mechanical Properties specimens obtained by tensile tests.

		Yield Strength (MPa)	Tensile Strength (MPa)	Percent Elongation (%)
Fillet welded joint	Ternary Mixture	146	315	22
	100%Ar	148	312	23
	Ar + 2%O_2	142	311	23

The graphics (figure 5A) are essentially a fingerprint of the weld and quantified repeatability and shows the stability of the MIG brazing process. Bouaifi (2003) showed that because there is around 20 % less energy input per unit length in MIG brazing than in others welding process, less heat enters the material and the risk of instability and distortion is greatly reduced.

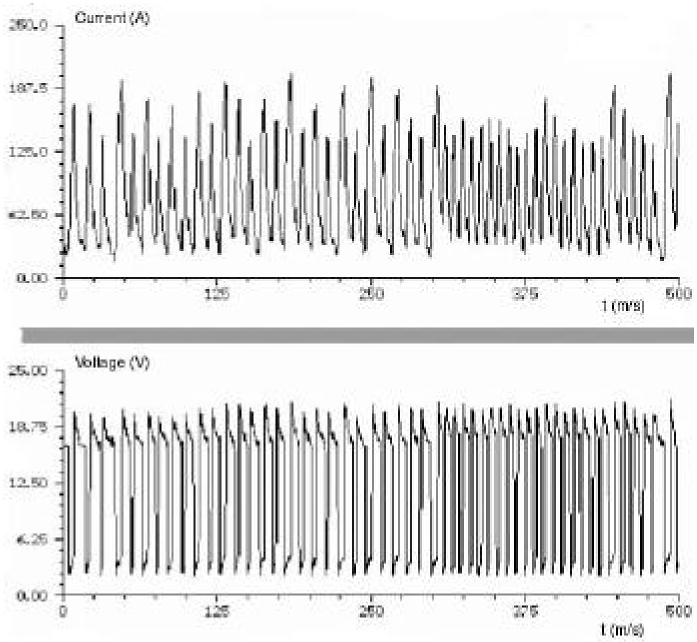


Figure 5. Graphics Currents versus Time and Voltage versus Time (m/s) showed the stability of the process. Shielding ternary condition.

The corrosion test did not impairment of corrosion resistance for condition ternary mixture (figure 6A). In the other condition, 100%Ar and Ar + 2%CO_2, have some white corrosion (figure 6B), typical for cooper-based brazing filler metal (National Defense Center-1998).

The black soot indicated a loss of zinc and, therefore, a lack of corrosion protection for the HAZ and the back side of the weld. Towsend (1991) and Kautek et al. (1994) found that a corrosion resistance reduction depends on the presence of specific alloying elements such as Cu, Si and Zn .

The primary purpose of mechanical plating processes is to enhance the corrosion protection of the parts plated. Zinc (and other active metals such as cadmium and aluminum) protects the underlying ferrous substrates by a process called sacrificial protection. This is sometimes called cathodic protection **.**

In this method of corrosion protection, the metals that are more active (chemically speaking, with more negative potentials or higher in the electromotive series), such as zinc, protect those that are less active or more noble by "sacrificing" themselves to protect the underlying more noble base metal. This process works effectively even if the sacrificial metal coating is slightly damaged.

The corrosion protection offered by zinc deposits is dependent upon three factors:

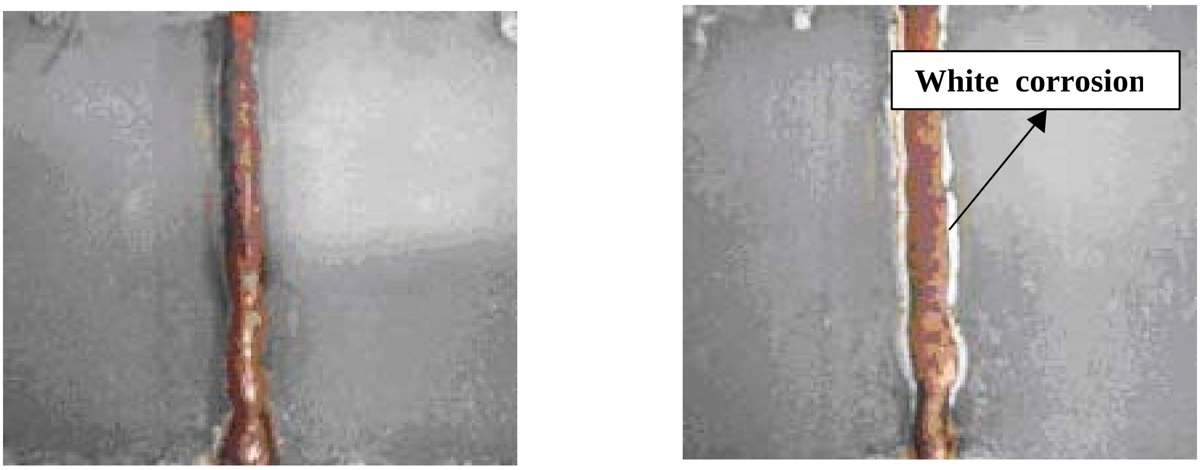
- Coating thickness
- Post-plate treatment(s)
- Environmental exposure

Zinc plating (without chromates) corrodes at rates which are dependent upon the severity of the environment. There is a significant body of data on local corrosion rates currently available.

Chromates protect the underlying deposit by delaying the onset of the white corrosion products. The chromating process is technically called a "conversion coating process"; in this process the parts are dipped into a solution containing chromates and the solution "converts" the topmost part of the zinc into zinc chromate; this zinc chromate is a highly effective corrosion inhibitor and the process binds it tightly to the surface of the zinc. It is important to recognize that the application of chromate conversion coatings is the most cost effective corrosion protection one can buy, Plating Systems & Technologies (2000).

Mechanical plating and mechanical galvanizing offer a proven means of protecting ferrous substrates from environmental corrosion. The nature of the deposit can be adjusted to provide protection from even the most severe environmental conditions.

Because the corrosion protection offered by sacrificial deposits is so lengthy, accelerated tests (the same test used in this work) are routinely used to predict the long-term effectiveness of the deposits. The parts are then evaluated for the first appearance of white corrosion products ("white rust" or oxides of zinc) and (later in the test) the formation of red rust, or base metal corrosion.



A B

Figure 6. A) Specimen corrosion for ternary mixture (Ar-O_2 -H_2) . B) Specimen Ar + 2%CO_2 mixture, where is possible to see white corrosion.

The freedom from spatter on the sheet and the very slight fusion of the zinc surface were confirmed by the results of EDX analyses at ternary condition (figure 7). To the others conditions the EDX analyses shows only Fe. By MIG brazing process with Ar-O_2 -H_2 , the base metal is not fused, so less zinc vaporizes.

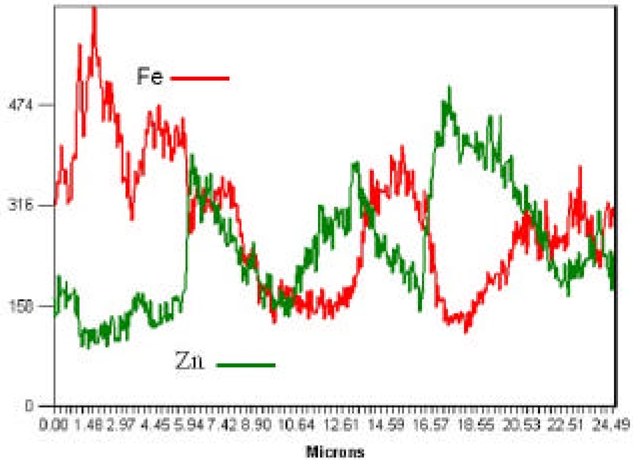


Figure 7. Spectrum line scanning of Zn and Fe elements by EDX analyses. Ternary mixture (Ar- $O_2 - H_2$) condition.

4. Conclusion

MIG-brazing was shown to offer clear advantages for this type of study, as compared to other welding processes, permitting to preserve the zinc layer. Mechanical testing and metallurgical cross sections confirmed that all shielding mixtures have weld joint integrity. The results show that ternary mixture was better than the other shielding mixtures due to the covering zinc layer preservation at accelerated corrosion test. The all joints exhibit excellent joint geometry without notches, and are free of cracks and pores.

5. Acknowledgements

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