

The Particularities of the CMT Braze-Welding Process Between Ferritic Stainless Steel - Magnesium Alloy

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Abstract. Joining of dissimilar materials with the CMT braze-welding process, ferritic stainless steel - magnesium alloy, offers important technical and economic advantages to the automotive industry. In the actual research paper we analyse the opportunity of realizing heterogeneous joints by the CMT process, using a layer of copper as a layer to be deposited firstly on ferritic stainless steel. Macro - and micrographic investigations, corroborated with hardness testing on (Cu-stainless steel, Mg - Cu) deposition by TIG, aim to highlight the process specificities and problems occurring in the interface areas of the joints made

1. Introduction

In the automotive industry, welding of dissimilar materials is of great interest [1, 2]. They have attracted significant interest when compared to the joints of similar materials. Components which have corresponding ductility, high strength, good corrosion resistance, and desirable thermal conductivities have been achieved through dissimilar materials welding [3, 4]. Several welding techniques have been reported, including Welding-Brazing, Arc, Friction, Friction stir, ultrasonic, laser, and hybrid laser-arc welding [1 - 6].

There is an increased risk of encountering problems during dissimilar welding, like the carbon migration from materials with higher carbon content to the materials with less carbon content, thermal expansion coefficient variation of materials, and challenges in the execution of the post-welding heat treatments [1].

The ferritic stainless steels are generally considered to have poor weldability when compared to the austenitic stainless steels. Consequently, few systematic studies have been conducted on their weldability other than to determine the effect of welding on their mechanical properties and corrosion resistance. In the first phase of this program the effects of elements such as C, N, Cr, Si, Mn, Mo, Ni, P, S, Ti, Nb, and Ta on the hot cracking susceptibility of Type 430 and Type 444L were studied [2].

Magnesium and its alloys are increasingly used in automobile industry and other fields for their lower density, higher specific strength, higher specific stiffness, etc. [3].

Copper and its alloys are also widely used in many fields due to their outstanding properties, such as good ductility, corrosion resistance, electric conductivity and thermal conductivity.

Hybrid structure of Mg/Cu dissimilar materials not only satisfies the requirements of electric conductivity, thermal conductivity and corrosion resistance but also meets the demand of light weight and high strength. However, joining of magnesium and copper has a metallurgical challenge because of the differences in their chemical and physical properties, and mass of brittle Mg_2Cu and $MgCu_2$ intermetallic compounds, which seriously decrease the mechanical properties of the joints. Therefore, it is mandatory to control the formation and growth of Mg-Cu intermetallic compounds [4].



This paper highlights the process specificities and problems occurring in the interface areas of the joints made of a ferritic stainless steels with a copper alloy and of copper alloy with a magnesium alloy.

2. Experimental procedure

In order to obtain a good joint between magnesium and stainless steel, with desired properties, due to their metallurgical incompatibility it is necessary to use a material as an intermediate layer between the two, with the condition to have a corresponding degree of compatibility. After consulting the literature the best candidate is copper as an intermediate layer.

Therefore, the materials used in the study include a 3 mm thick ferritic stainless steel sheets (30x30 mm) and a 3 mm thick T2 pure copper sheets (30x30 mm). As a filler material was used AZ31 magnesium wire and a T2 pure copper wire. The chemical composition of the materials used, per the manufacturer's data sheet, is presented in Table 1.

Table 1. Chemical composition.

Material	Elements, % wt.											
	Fe	Cr	Mn	Mg	Ni	S	Zn	Al	P	Cu	Si	O
Ferritic steel W1.4713	Balance	7.1	0.68	-	-	0.011		0.72	0.026	-	0.74	
Mg-AZ31	0.005	-	1.0	Balance	0.005	-	1.3	3.5		0.01	0.05	-
T2 Copper (ECu-58)					0.021		0.025			Balance		0.034

Before welding, the oil on substrates (Cu-T2) surface were removed by a wire brush and acetone. The experimental setup is presented in Figure 1.

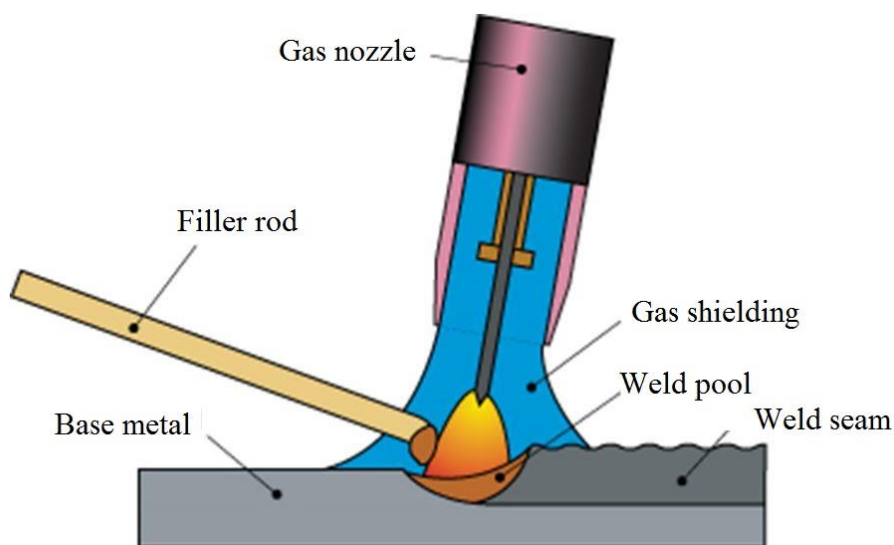
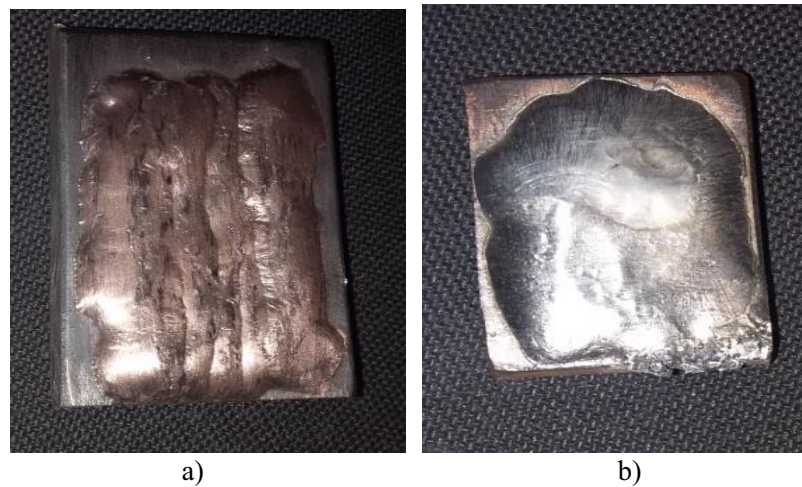


Figure 1. Experimental setup.

In order to study the peculiarities between the ferritic stainless steels, magnesium alloy and the intermediate layer of copper, the following depositions were carried out:

- Deposition of a copper layer on a stainless steel sheet;
- Deposition of a magnesium layer on a copper sheet.

Figure 2 a, b shows weld appearance of the Mg-AZ31 to Cu-T2 and the weld appearance of Cu-T2 to the ferritic stainless steel. The TIG welding was carried out using Fronius Magicwave 3000 welding machine. The main welding parameters, such as welding speed, wire feed speed, welding current and welding voltage, were presented in Table 2.

**Figure 2.** Welding deposition

a) - Cu-T2 to the ferritic stainless steel; b)-Mg-AZ31 to Cu-T2.

In addition, 99% argon shielding gas with a flowrate of 15 L/min was used throughout the experiments .

Table 2. Welding parameters.

Material	Polarity	Welding speed	Wire feed speed	Welding current and welding voltage
Cu-T2 to the ferritic stainless steel	DC -	1 mm/s	3mm/s	180/20.5
Mg-AZ31 to Cu-T2	AC	1 mm/s	2mm/s	215 / 21.5

The weld geometry was studied at the weld zones to observe the changes in the seam profile, and weld joint microstructures through optical microscopy (Leica, DM IL M LED).

Metallographic investigations were conducted on a region of 30 mm × 10 mm × 2 mm which involved all of the weldment regions (base metal, heat-affected zone, and weld). The samples were etched for a period of 20 s. The compound weldment regions were polished with alumina and distilled water, using sheets of SiC of varied sand sizes ranging from 240 to 1200. The polishing process followed regular metallographic techniques to achieve a perfect mirror finishing of approximately 1 μm.

Figure 3 shows the weld seam dimensions (width of weld seam, depth of penetration), while the micro-hardness was measured at 1 mm from the top surface of the welded joint. Vickers micro-hardness technique was used to study the mechanical behavior by using a hardness tester (ZWICK 3212). Hardness measurements were studied across 3 zones the interface. Standard HV2 – hardness method was used, at consistent intervals of 1 mm.

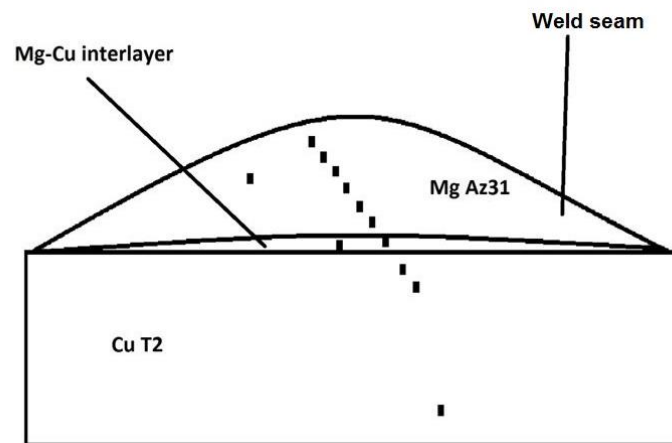


Figure 3. Weld seam profile and the micro-hardness measurements direction.

3. Results and discussions

In order to understand the mechanisms of WIG deposition of Mg–AZ3 to Cu–T2 and Cu-T2 to the ferritic stainless steel W14713, the microstructures of the joints were analysed. Figure 4 shows the macroscopic cross-section of Mg-Cu WIG joints



Figure 4. Macroscopic cross-section of Mg-Cu WIG deposition.

As shown in Figure 4, the joint was composed of three zones:

- Mg fusion zone, formed between Mg base metal and weld metal;
- weld metal zone;
- brazing interface zone formed by molten weld metal and local molten Cu base metal.

Figure 5 shows the macroscopic cross-section of Cu deposited on the ferritic stainless steel

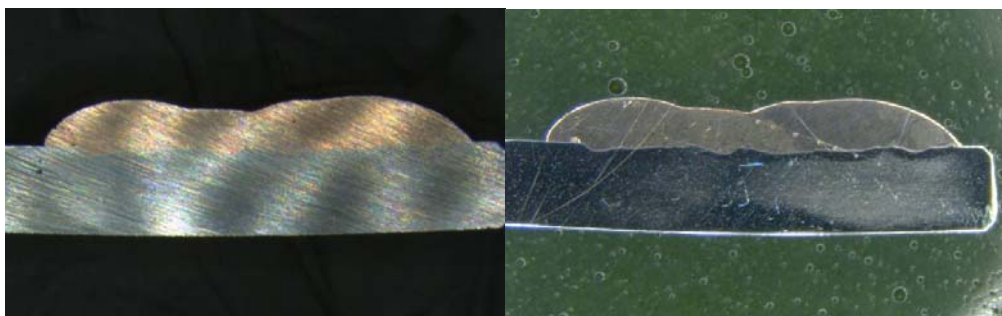


Figure 5. Macroscopic cross-section of Cu to stainless steel deposition.

Figure 6 a, b, c, shows the microstructures of various regions of Mg-Cu WIG joint

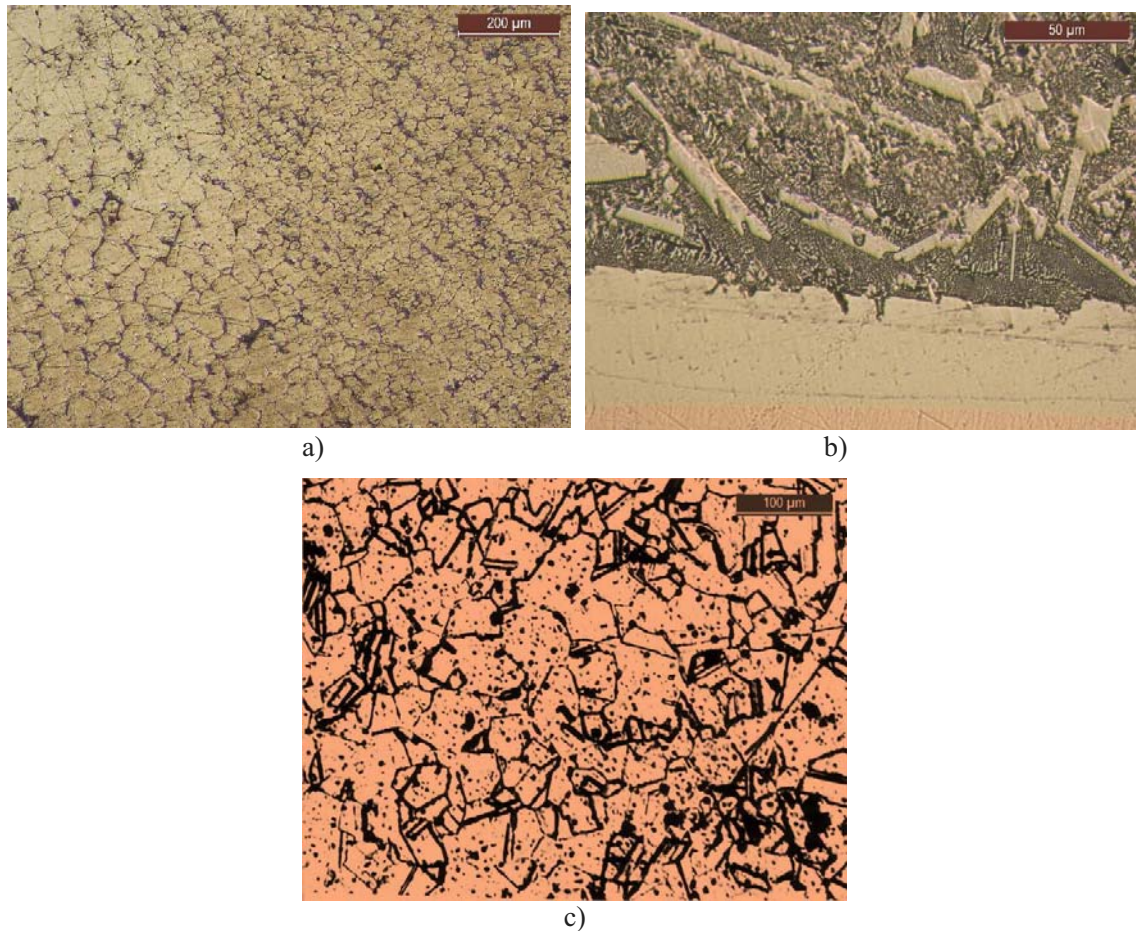
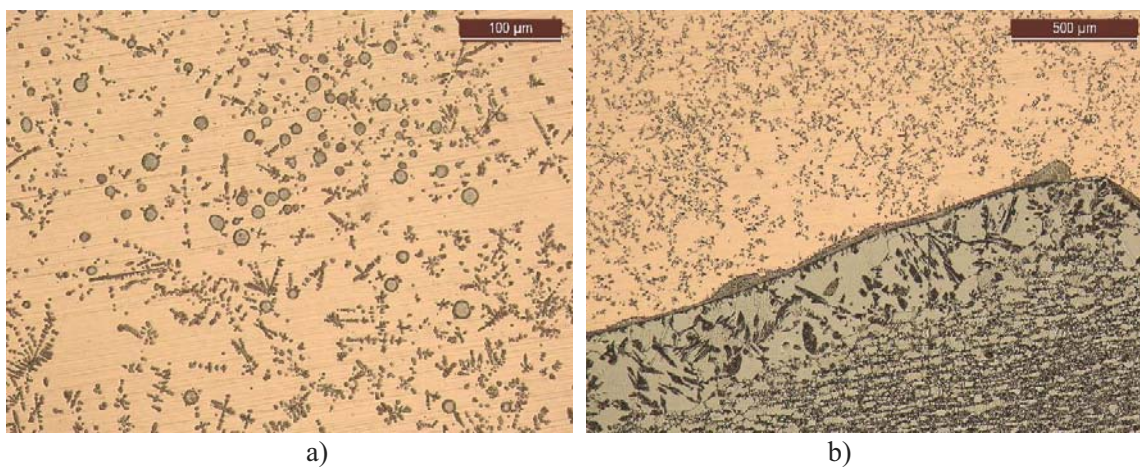
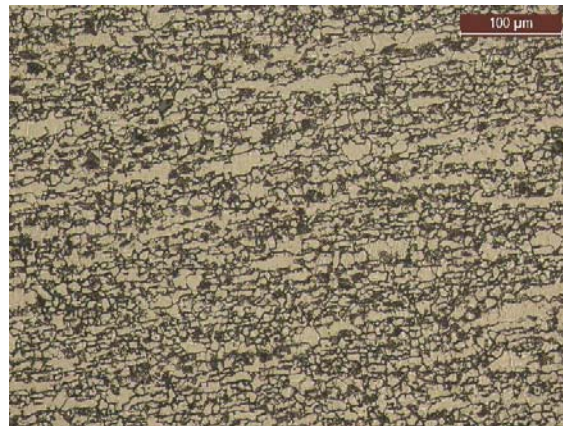


Figure 6. Microstructure of the joint
 a) – deposited material; b) – fusion line; c) – base metal-Cu.

Figure 7 a, b, c, show the microstructures of various regions of Cu deposited on the ferritic stainless steel





c)

Figure 7. Microstructure of the weld

a) - deposited material; b) – fusion line; c) – base metal.

Figure 8 presents the hardness distribution of the Mg deposition on Cu. From Fig. 7, high hardness appears in the brazing interface layer (Fusion line - FL), which is composed of series intermetallic compounds, consistent with Figure 6.

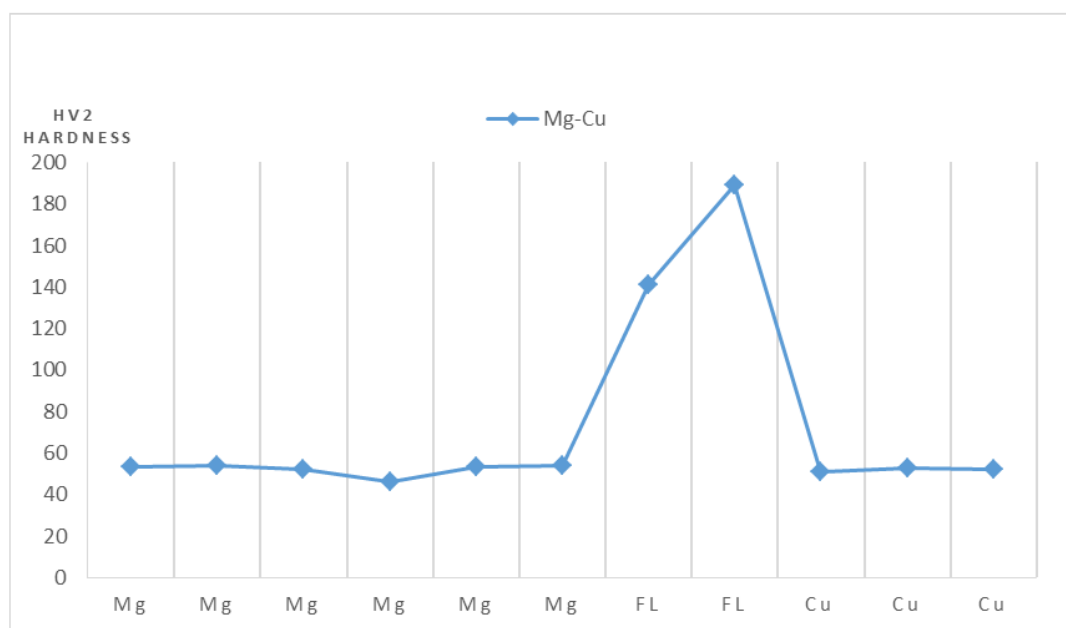
**Figure 8.** Distribution of hardness.

Figure 9 presents the hardness distribution of the Cu-T2 deposition on the ferritic stainless steel.

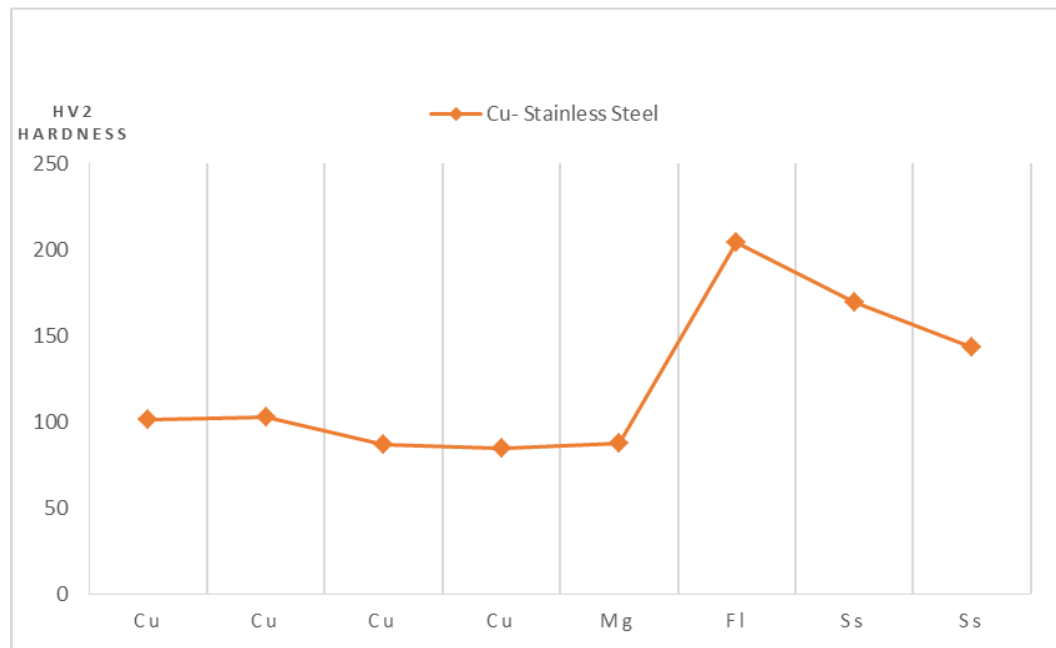


Figure 9. Distribution of hardness.

4. Conclusions

1. Joining of ferritic stainless steels with magnesium alloys remains a topical issue because it can not be achieved with the usual welding techniques.
2. The application of the CMT brazing process using an intermediate Cu layer can lead to solving the incompatibility problems between the two dissimilar materials.
3. Changing the chemical composition of the welding bath avoids the formation of brittle intermetallic phases between Fe and Mg, and the working environment of the process limits the rapid oxidation of Mg.

5. References

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