Investigation of Corrosion Resistance of Cold Metal Transfer Welded AA7075 Aluminum Alloy Galvanized Steel Couples

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ABSTRACT

Corrosion is the degradation of the metal as a result of chemical reactions with its surroundings. However, corrosion can be predicted, in some cases significantly slowed down or prevented. In this study, the effect of galvanic corrosion formation on the tensile strength of AA7075-galvanized steel joints produced by cold metal transfer welding, which is one of the manufacturing methods used in forming many constructions, was investigated. The aluminum and steel pair are difficult to combine with other welding methods. Joining is provided by this method. Corrosion in this joining was investigated in this article. As a result, increased heat input during welding adversely affected galvanic corrosion and increased material dissolution.

Keywords: AA7075, cold metal transfer, corrosion, welding, steel

Soğuk Metal Transfer Kaynağı ile Birleştirilmiş AA7075-Galvanizli Çelik Çiftinin Korozyon Direncinin İncelenmesi

ÖZ

Korozyon, metalin çevresi ile arasındaki kimyasal reaksiyonların bir sonucu olarak bozulmasıdır. Fakat korozyon, önceden tahmin edilebilir, bazı durumlarda önemli ölçüde yavaşlatılabilir veya önlenebilir. Bu çalışmada, pek çok konstrüksiyonun oluşturulmasında kullanılan imalat yöntemlerinden biri olan kaynak çeşitlerinden soğuk metal transfer kaynağı ile üretilen AA7075-galvanizli çelik bağlantılarda galvanik korozyon oluşumunun ve farklı bağlantıların gerilme dayanımına etkisi incelenmiştir. Alüminyum ve çelik çifti diğer kaynak yöntemleriyle birleştirilmesinin zor olduğu bir çifttir. Bu yöntem ile birleştirilme sağlanmıştır. Bu çalışmada, bağlantıda oluşacak korozyon incelenmiştir. Sonuç olarak, kaynak sırasında artan ısı girişi galvanik korozyonu olumsuz yönde etkiledi ve malzeme çözünmesini arttırdığı tespit edilmiştir.

Anahtar Kelimeler: AA7075, Çelik, Kaynak, Korozyon, Soğuk Metal Transfer

INTRODUCTION

Aluminum alloys are attractive materials for automotive and aerospace industries owing to their lightness, high strength, good fracture strain and corrosion endurance [1-3]. Although aluminum alloys are found suitable in particular for automobiles, it would be very expensive to produce whole body structure only with aluminum. Thus, replacing some of the steel parts of a car with aluminum alloys sounds a workable solution that demands riveting or welding these dissimilar materials [3, 4]. The problems during the welding of aluminum and steel arise from their different chemical, physical properties and formation of brittle intermetallic compounds [2, 3]. Cold metal transfer (CMT) welding is an economic method with low initial investment cost and is well known with its low heat input characteristic [5] that enables a significant control on growth of intermetallic compounds. AA7075 alloy is preferred in particular in aircraft applications [4]. The use of welding methods instead of mechanical connections is a more weight-reducing solution. But there has not been much work on this issue. However the developing techniques make possible the welding of dissimilar materials and give the idea of using high strength AA7075 alloy with steel in automobile bodies. In addition to CMT welding, several welding techniques can be also applied to join aluminum to steel such as friction stir and laser welding techniques [6]. These techniques eliminate or minimize the problems in welding dissimilar metals. However, another issue shows up after the welding: the galvanic corrosion that occurs between these different materials in contact [7].
Borrisutthekul and et al.(2018), investigated effect of zinc-coated layer on steel sheet of dissimilar metals welding between SCGA270C steel and A5052 aluminum alloy by GTAW [8]. In this study, AA7075 aluminum alloy and galvanized steel are welded by cold metal transfer method. It is aimed to reveal the changes in macro scale such as material loss and the reduction in tensile strength due to the galvanic corrosion between AA7075 and steel.

MATERIAL and METHOD

AA7075 (Table 1) and galvanized steel (Table 2) sheets with dimensions of 500mmx200mmx2mm were welded by cold metal transfer (CMT) welding (Table 3) using ER4043 (AlSi5) filler wire. Argon gas was used as protect of weld metal.

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Table1. Chemical compositions of AA7075 aluminum alloy and ER4043 filler wire

Element	Mg	Si	Cr	Cu	Fe	Zn	Mn	Al
AA7075 (T6)	2.43	0.071	0.187	1.675	0.17	6.36	0.03	
ER4043	-	5	-	<0.01	<0.3	<0.01	<0.01	Rest

Table2. Chemical composition of galvanized steel

C	Mn	P	S	Si	Ti	Fe
0.051	0.216	0.018	0.013	0.014	0.001	Balance

Table3. CMT welding parameters

Sample	Current (A)	Voltage (V)	Welding speed (m/min)	Wire feed rate (m/min)	Heat Input (J/mm)
A	81	11	1	4.8	48.11
B	86	12.3	0.5	4.6	114.24

Before the microstructural examinations, the samples were cut (20mmx30mmx2mm) and polished. Keller for AA7075 aluminum alloy and Nital for galvanized steel solutions were used. In addition to the microstructure samples, the tensile test specimens were held in a 3.5 wt. % NaCl aqueous solution for five months in order to investigate the effect of corrosion on the tensile strength of AA7075-steel. The tensile test of the welded samples was carried out at a speed of 1 mm/min at room temperature at SHIMADZU (250 kN) in MCBÜ DEFAM. SEM-EDX analyzes performed in İYTE MAM SEM-EDX device.

RESULTS AND DISCUSSION

Microstructure

Figure 1 shows the grain coarsening caused by the increased heat input in the weld metal and in HAZ of AA7075 base metal was investigated by microstructural studies. A thin, dark layer between the aluminum based weld metal and steel can be seen in Figure 1a and 1b. SEM-EDX analysis was taken along a line from sample B. As it is seen in Figure 1, the percentage of iron and aluminum through the line changed gradually that indicates the formation of Al-Fe intermetallic compounds in the thin, dark layer.

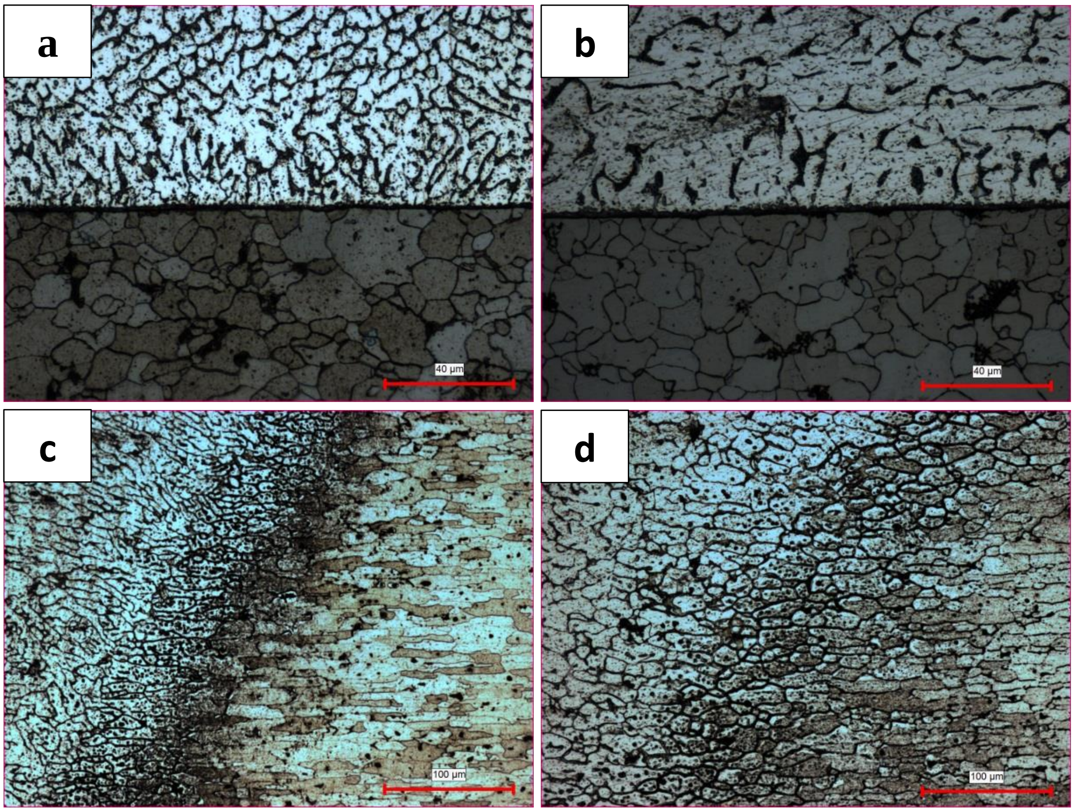


Figure1. Microstructure of weld metal/steel interface of: a) Sample A, b) Sample B and AA7075/weld metal interface of: c) Sample A, d) Sample B

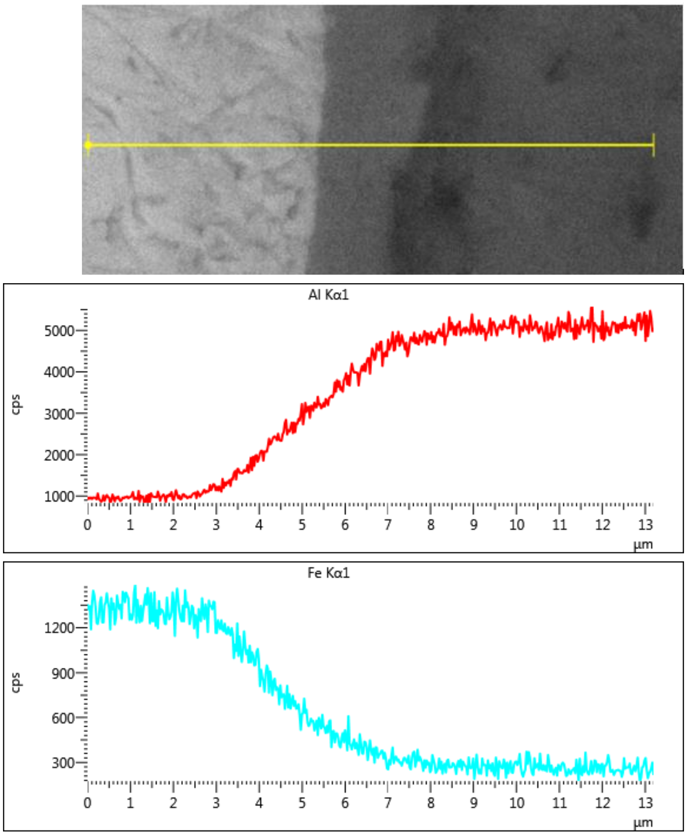


Figure2. SEM-EDX line analysis of Sample B

In Figure 2, Selected area is scaned to better detect element transitions in İYTE SEM-EDX device. The presence of elements (Al and Fe) in the intermediate weld metal can be seen.

Corrosion

Numerous parameters such as pores, cracks, residual stresses, wrong fill material selection affect the corrosion resistance of welded parts [9]. Besides, the potential occurrence of the galvanic corrosion increases in hybrid structures of steel and aluminum due to the different electrochemical behavior of these two materials. Moreover, the sheet metal which was used in the welding process is produced by plastic deformation processes that induce the residual stresses. After the welding process, residual stresses promote the activation of regional stress corrosion cracking and may reduce the strength of the connection [10]. According to galvanic series of various or several metals in sea water (Table 4), aluminum is more anodic than steel. Just say as expected, material loss occurred in the AA7075 base material (Figure 3). Besides, Figure 4 revealed that weld tip also suffered from corrosion. Several works exposed that the zinc layer on galvanized steel is dragged towards the weld tip and forms a zinc-rich zone [11, 12, 13]. Consequently, zinc as an active metal (Table 4) caused the dissolution of weld tip (Figure 4).

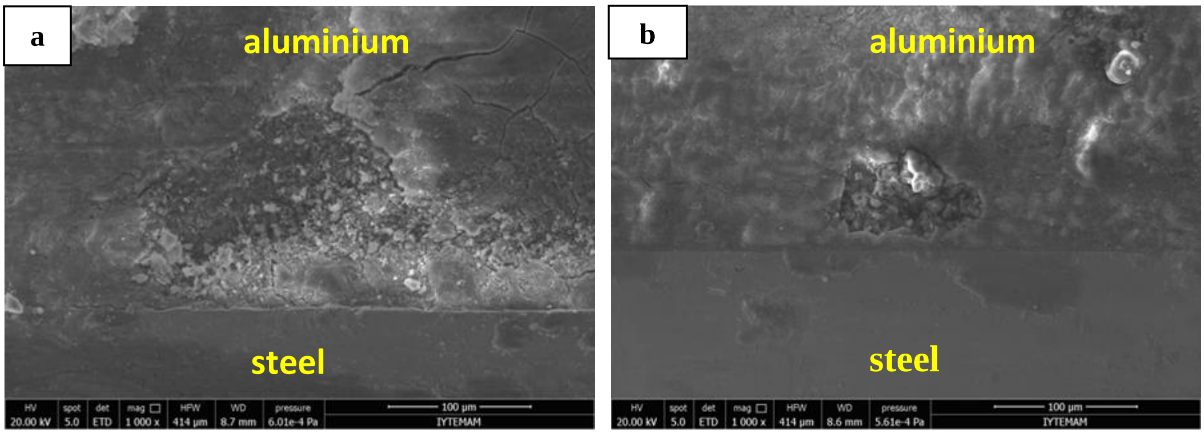


Figure3. SEM images of the surfaces of the corrosion in Sample a and Sample b

Table4. Galvanic series of some metals in sea water [14-15]

Active, Corroded ↑			Noble, Protected ↓
	Magnesium	Copper	
	Zinc	Nickel	
	Beryllium	Silver	
	Aluminium	Titanium	
	Low carbon steel	Zirconium	
	Alloyed steel	Gold	
	Cast iron	Platinum	

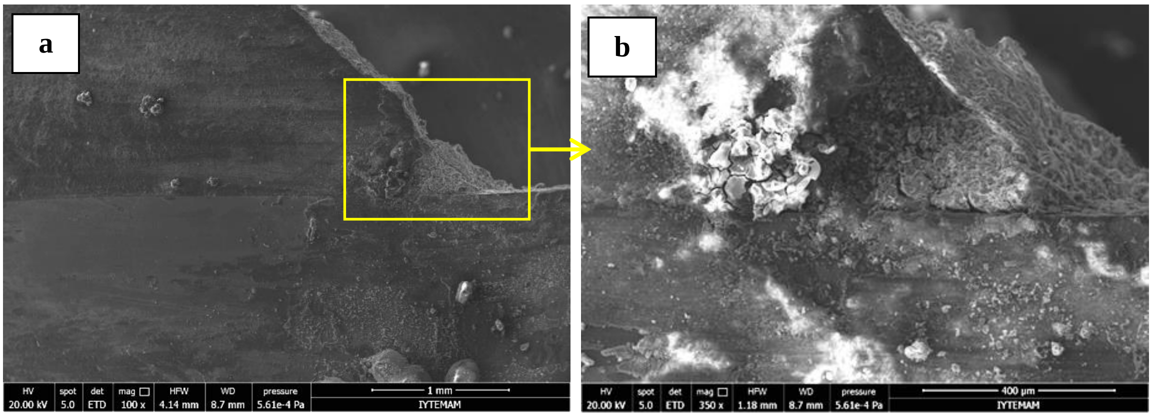
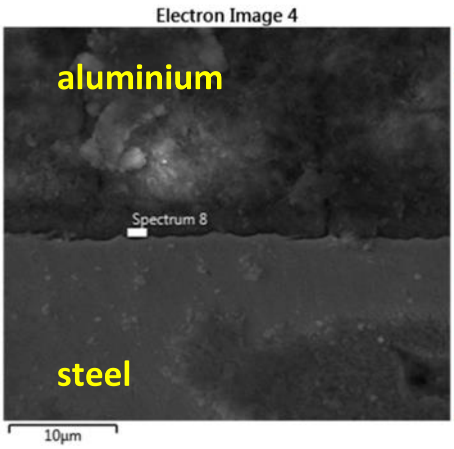


Figure4. Corrosion in zinc-rich zone of sample B



Element	% ağ.	% at.
O	29.25	53.40
Mg	1.80	2.16
Al	12.99	14.06
Si	2.28	2.37
Ca	0.24	0.17
Fe	51.95	27.17
Zn	1.50	0.67
Total:	100.00	100.00

Figure5. SEM-EDX analysis of Sample B after corrosion

Tensile testing

Material loss was observed in AA7075 base metal of tensile specimens that were held in 3.5 wt. % NaCl solution (Figure 6). More material loss occurred in sample B than sample A because of heat input. Although increased weld heat input enhanced the tensile strength of AA7075-steel joint, it caused a change in microstructure of AA7075. It is known that $MgZn_2$ precipitates have a great influence on corrosion [16]. A change in size and distribution of these precipitates may worsen the corrosion resistance and increase the material loss (Figure 7). In general, increased heat input deteriorates the mechanical properties of welded parts. However, thickness and mechanical properties of intermetallic compound layers might affect the overall strength of AA7075-steel joints. The galvanic corrosion between aluminum and steel caused material loss in the aluminum base material that decreased the joint strength approximately 40% (Figure 7).

CONCLUSIONS

AA7075 and galvanized steel sheets were welded by cold metal transfer welding successfully. The effect of galvanic corrosion on AA7075-steel joints can be summarized as follows:

1. An intermetallic layer of Al-Fe formed between the galvanized steel and weld metal.
2. Material loss was observed only in aluminium alloy due to its anodic characteristic.
3. With increasing heat input, material dissolution increased and galvanic corrosion was adversely affected.

4. As a result of the dissolution of AA7075 base metal and galvanic corrosion, the tensile strength of AA7075-steel joints was reduced.

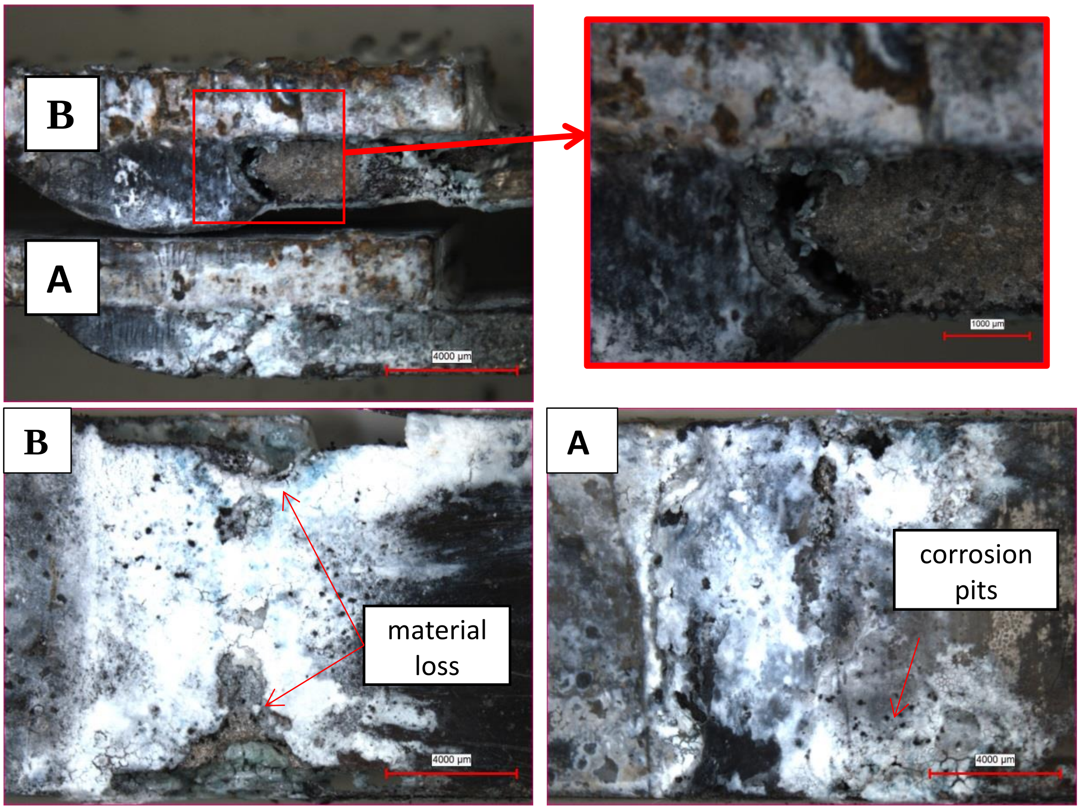


Figure6. Tensile test specimens after corrosion test on Sample A and Sample B

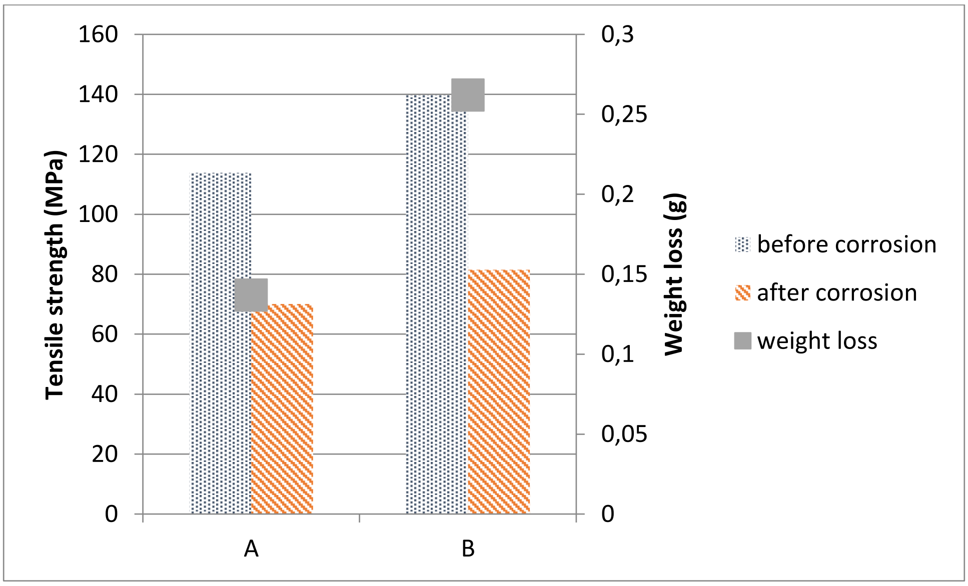


Figure7. Tensile strength before and after corrosion

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