

EFFECT OF CORROSION PROCESS ON MECHANICAL PROPERTIES AND ACOUSTIC EMISSION CHARACTERISTICS OF AL/ZINC-COATED STEEL WELDED BY COLD METAL TRANSFER

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Abstract: The objective of present article is to study mechanical properties and acoustic emission (AE) characteristics occurring in cold metal transfer (CMT)-welded specimens subjected to corrosion process and tensile testing. In this experiment, to provide test specimens, Al alloy AlMg3 sheets and zinc-coated steel DX51D sheets were joined by using CMT welding with AlSi5 as filler material. The experiment was divided into two parts; first is studying AE signals detected from test specimens being under salt-spray testing, and second part is conducting tensile testing of both corrosive CMT-welded specimens and non-corrosive CMT-specimens with AE technique. From the experimental results, it found that corrosion process appearing on test specimens clearly decreased the strength of test specimens. Moreover, using AE technique was able to display AE signals generated by test specimens during tensile testing interestingly. Therefore, examining the quality of CMT weldment by using AE method is one of interesting technique for improving the manufacturing process in industrial sections effectively and safely.

Key Words: acoustic emission method, cold metal transfer, corrosion, tensile testing

INTRODUCTION

Acoustic emission (AE) is potential nondestructive evaluation (NDE) techniques and it can be effectively used for structural integrity monitoring applications and characterizing damages in materials (Kordatos et al. 2012). This technique detects elastic waves generated within a test specimen by such mechanisms as corrosion, plastic deformation, fatigue, and fracture (Dostal et al. 2011). Generally, AE systems contain sensor, preamplifier, filter, and amplifier, along with measurement, display, and storage equipment. A suitable sensors are placed on the surface of specimens the transient waves generated by the crack propagation incidents. Subsequently, the characterization and quantification of the damage level could be performed using appropriate AE descriptors (Sriwongras et al. 2014).

Cold metal transfer (CMT) is completely new technology with respect to both welding application and welding equipment. CMT is not only completely new technology, but it also enhances MIG application areas, allowing the arc joining of steel to aluminum in a reproducible manner for the first time. CMT can be described as a Gas Metal Arc Welding (GMAW) process where heat input is low compared to the conventional dip arc process (Beytullah et al. 2013). In the CMT process the wire is not only pushed towards but also drawn back from the work piece and oscillating wire feeding with an average oscillation frequency up to 70 Hz is used (Rosado et al. 2008).

The aim of the study is to investigate the feasibility of using AE method for detecting AE signals generated from CMT-welded specimens during being tested by salt-spray testing and tensile testing in order to evaluate the corrosive and strength conditions of test specimens that are dissimilar metals connection (Al alloy/zinc-coated steel).

METHODS AND MATERIALS

Experimental procedures

Comparing the mechanical and acoustic emission properties of both corrosive CMT-welded specimens and non-corrosive CMT-welded specimens was carried on in this experiment. Ten CMT-welded specimens as shown in Figure 1 were used to be test specimens. The experimental procedures were conducted in two parts continuously; first parts of experiment is that five CMT-welded specimens were placed in salt-spray chamber in order to be corroded by corrosion process at a specific period of time and, to monitor AE signals on test specimen during corrosion process, one of them was equipped with an AE sensor near the position of its joint. For second part of experiment, all corrosive CMT-welded specimens and five non-corrosive CMT-welded specimens were individually tested by using universal testing machine (UTM) so as to study the mechanical properties of both corrosive specimens and non-corrosive specimens and, during each specimen tested by UTM, it would be also equipped with an AE signals beside its joint in order to detect AE signals.

Test specimens and filler material

1.5 mm thick Al alloy AlMg3 and 1.5 mm thick galvanized steel DX51D sheets were used in this experiment. Typical chemical composition and mechanical properties of these materials are provided in Table 1 and Table 2, respectively. Welding wire AlSi5 having a diameter of 1.6 mm was used as filler material. Table 3 provides the chemical composition of AlSi5. The lap-shear joint configuration as shown in Fig. 1 was fabricated by AlMg3 and DX51D sheets and each sheet has dimension of 50 x 20 x 1.5mm. The Al alloy AlMg3 sheet was placed on top of the galvanized steel DX51D sheet in a lap configuration with an overlap distance of 20 mm.

Table 1 Chemical compositions of Al alloy AlMg3 and galvanized steel DX51D sheets (in wt%)

Material	Al	Be	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn	C
AlMg3	Balance	0.0008	0.35	0.1	0.4	3.9	0.1	0.25	0.2	0.2	-
DX510	-	-	-	-	99.3	-	0.5	0.1	-	-	0.1

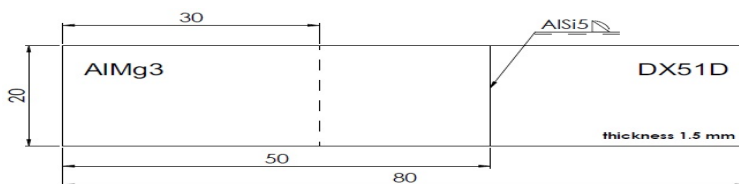
Table 2 Mechanical properties of Al alloy AlMg3 and galvanized steel DX51D sheets

Material	Yield strength (MPa)	Ultimate strength (MPa)	Elongation at Break (%)
AlMg3	125	220	25
DX510	280	400	28

Table 3 Chemical compositions of AlSi5

Al	Be	Cu	Fe	Mg	Mn	Si	Ti	Zn
Balance	0.0008	0.3	0.8	0.05	0.05	6.0	0.2	0.1

Figure 1 Dimension of a test specimen



Acoustic emission (AE) device

To study the characteristics of AE signals generated by CMT-welded specimens subjected to corrosion process and tensile testing, AE method was employed as AE detector. AE device manufactured by Dakel company (Czech Republic) was selected to be AE detector in this experiment. The major components of used AE system consist of broadband sensor, preamplifier, acquisition system, software and computer. To operate AE system interestingly, using AE method with test specimens can be separated into 2 parts; first part is employing AE method for monitoring the AE signals of test specimens being under salt-spray chamber, and second part is conducting AE method for examining the AE signals of test specimens being under tensile testing. For analyzing the results

properly, root mean square (RMS), the number of counts and the accumulation of event number are considered as AE parameters.

Salt-spray testing

Salt-spray tests have been used for more than 90 years as accelerated tests in order to determine the corrodibility of nonferrous and ferrous metals as well as the degree of protection afforded by coating on a metallic base (Davis 2003). Therefore, in this experiment, salt-spray chamber was used to accelerate the corrosion process in all test specimens. The salt solution was prepared by dissolving 5 ± 1 parts by weight of sodium chloride in 95 parts of distilled water, and the pH of the salt solution was provided in range of 6.5 to 7.2. The temperature of the salt spray chamber was controlled to maintain 35 ± 1.1 or -1.7 °C within the exposure zone of the closed chamber, and the duration of this test was 200 hours.

Mechanical testing

Specimens in Fig.1 machined from the weldment were subjected to quasi-static tensile loading on a ZDM 5/51 universal testing machine with capacity of maximum load of 50 kN. Load vs. displacement curves were obtained at a stroke rate of 20 mm/min. The joint strength is evaluated by the peak load. Ten specimens which were five corrosion specimens and five non-corrosive specimens were performed.

RESULTS AND DISCUSSIONS

Experimental result of AE method and salt-spray testing on test specimens

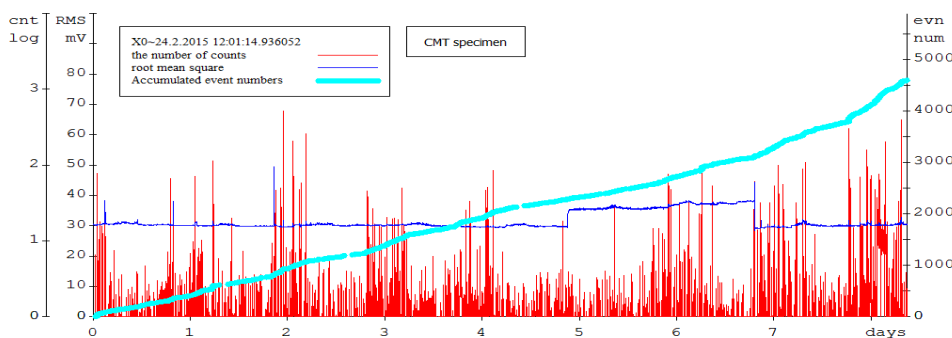
After experimenting the test specimens being under salt-spray testing with AE method for 200 hours, corrosive CMT-welded specimen can be shown in Figure 2. From Figure 2, corrosion process occurring on test specimen mostly appeared on the surface of galvanized steel DX51D sheet whereas the surface of Al alloy AlMg3 was corroded by salt-spray testing less than corrosion process happening on DX51D sheet.

Figure 2 Corrosive specimen after being subjected to corrosion process in salt-spray chamber



For AE results detected from specimen tested by salt-spray testing as shown in figure 3, it illustrated that the value of accumulation of event number, which is one of relevant AE parameters, increased continuously, especially in last day of experiment, and also values of root mean square and the number of counts were continuously detected by AE sensor throughout experimental period.

Figure 3 AE parameter values generated from test specimen versus experimental periods during salt-spray testing



Experimental result of AE method and tensile testing on test specimens

After tensile testing used for acquiring the mechanical properties of five corrosive CMT-welded specimens and five non-corrosive CMT-welded specimens, this experimental results demonstrated that the maximum tension forces before reaching the rupture point of five corrosive CMT-welded specimens were equal to 2000, 2078, 2096, 1979 and 2010 kN, and that of five non-corrosive CMT-welded specimens were equal to 2250, 2378, 2326, 2249 and 2235 kN. For AE results monitored during tensile testing, figures 5 and 6 show AE signals monitored during tensile testing of a corrosive specimen and a non-corrosive specimen, respectively. All corrosive specimens had the same pattern of detected AE signals during tensile testing and also all non-corrosive specimens had the same pattern of detected AE signals during tensile testing. As can be seen from figures 4 and 5, AE signal parameter, which is root mean square, can display the warning signals before all specimens reaching their rupture point and, moreover, the maximum RMS value of all specimens completely appears at position of rupture point of all test specimens.

Figure 5 AE characteristic (RMS) and mechanical properties (force and displacement) of a corrosive CMT-welded specimen

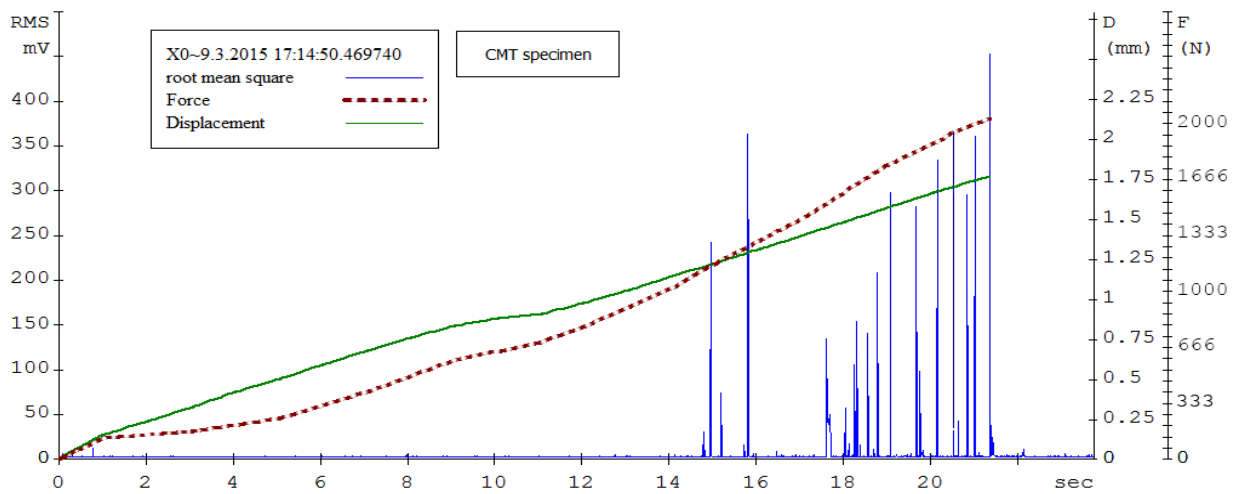
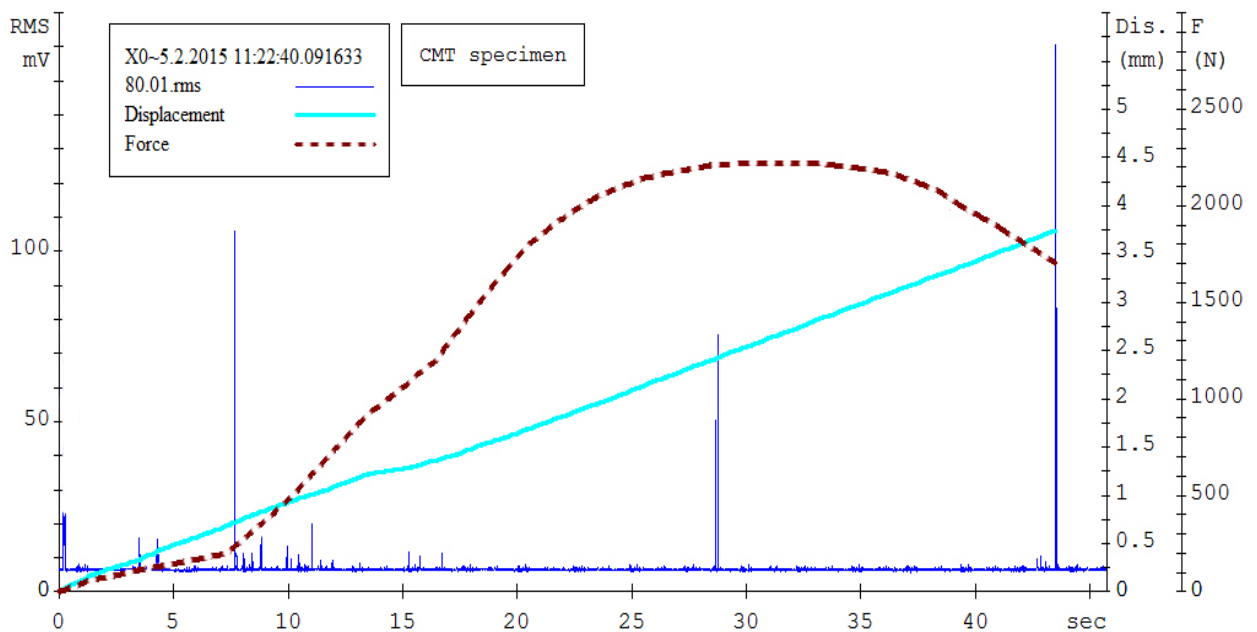
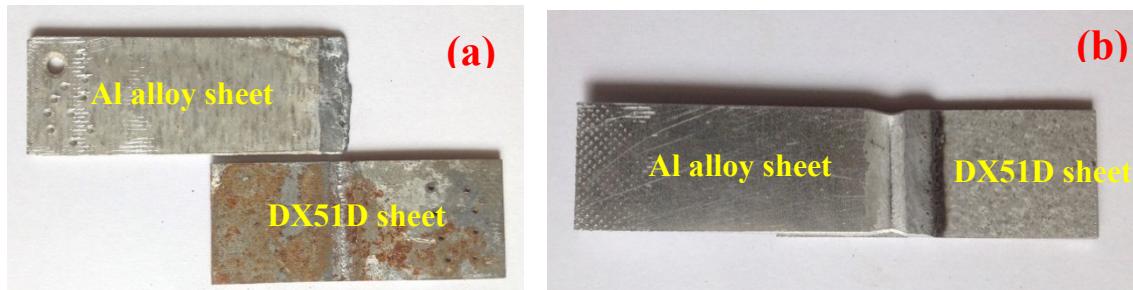


Figure 6 AE characteristic (RMS) and mechanical properties (force and displacement) of a non-corrosive CMT-welded specimen



To evaluate the damages of joint of welded specimens after tensile testing, two types of different fracture were found as shown in Figure 7. All corrosive CMT-welded specimens were broken at the interface between the weld metal and galvanized steel DX51D as displayed in Figure 7(a) and all non-corrosive CMT-welded specimens were fractured at the fusion zone near the Al alloy AlMg3 sheets as illustrated in Figure 7 (b).

Figure 7 Corrosive CMT-welded specimen (a) and non-corrosive CMT-welded specimen (b) after being tested by UTM



From experimental results in this study, corrosion process occurring on CMT-welded specimens cause the strength of these specimens decreasing. This is because corrosion process that happens on specimens decreases the strength of interface between weld metal and DX51D sheet. However, using AE method is able to examine strongly AE signals generated from CMT-welded specimens subjected

to tensile testing before test specimens reach their rupture point and break. This result is consistent with another publication (Haneef et al. 2015). Therefore, application of AE technique for monitoring CMT-welded specimen is one method of evaluation the quality of manufacturing process in industrial sections alternatively.

CONCLUSION

The intention of this study wants to investigate the effect of corrosion process on mechanical properties and AE characteristics of CMT-welded specimens. The experimental results can be summarized as following;

1. AE method is able to detect AE signals generated by CMT-welded specimens being under corrosion process in order to evaluate how quick corrosion occurs on test specimens.
2. Corrosion process happening on CMT-welded specimens distinctively reduces the strength of test specimens during tensile testing.
3. AE signals detected from CMT-welded specimens using AE technique during tensile testing is able to be warning signals for avoiding the situation that investigated specimens fracture at their rupture point.

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