THE EFFECTS OF RESIDUAL STRESS AND INTERFACE CONDITION OF DISSIMILAR SOLID PHASE WELDING MATERIALS ON CORROSION RESISTANCE AND JOINT STRENGTH

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Keywords: *Friction welding, Galvanic corrosion, Residual stress, Intermetallic compound*

1. Abstract

Friction welding (hereinafter called FW) which is a representative method of solid state junction to metals is widely used in industrial parts because FW has high freedom of material combination and high strength of junction.
However, a dissimilar-metal jointing material can hardly be used under the corrosive atmosphere so that the base metal is corroded violently by the galvanic corrosion based on the electric potential difference between both metals. If the matter can be solved, FW can be used variously in industrial fields.

Therefore, this study is to clarify the effects of corrosion influence for the following items, corrosion environment, electric potential difference between the different materials, residual stress induced by joint and state of the welded interface. Finally, it aims to find the clues for the countermeasures.

2. Experimental procedure

2.1. Weld joint Specimen and Materials

All Joint test specimens were the gauge length of 40mm, the diameter of 12mm and an overall length of 100 mm. The joint conditions of each test specimens are shown in Table 1. In order to investigate the influence of metal potential difference for corrosion behavior, the one side was chosen of A6063 and the other side was the choice among the 3 kinds of different materials, as shown in case1 in Table 1. Moreover, the 3 kinds of that for the S15CK and Ti-6Al-4V joint material were carried out in order to clarify the influence of difference a joint condition for corrosion behavior as shown in case2 in Table 1. S15CK is the one with low carbon steels and its chemical compositions are:0.15C-0.5Mn-0.2Si-0.27P-0.21S-Fe.

Table.1 Weld joint conditions
(Rotation speed:1650rpm,Upset time: 6.0sec)

	Material	Condition of Interface	Friction press [Mpa]	Friction time [sec]	Upset press [Mpa]
Case1	A6063/S15CK	Better	25.0	5.0	75.0
	A6063/S15CK	Best	30.0	1.5	240.0
	A6063/SUS304	Best	Ditto	Ditto	Ditto
Case2	Ti-6Al-4V/S15CK	Best	120.0	7.0	330.0
	Ti-6Al-4V/S15CK	Worse	90.0	2.0	270.0
	Ti-6Al-4V/S15CK	Worse(IMC)	30.0	8.0	30.0
Case 3	CP-Ti/S15CK	Better	90.0	2.0	270.0
	CP-Ti/S15CK	Best	30.0	3.0	Ditto

2.2. Corrosive environment

$FeCl_3$ solution liquid was used as a corrosive liquid. The concentration of solution was 6%, and provided in accordance with the method of ferric chloride tests for stainless steel (JISG0578). The specimen was fully immersed in the solution liquid(140ml: 0.0112ml/mm2) for 2 weeks. The solution liquid in a polypropylene container is replaced once a week.

Two kinds of temperature of corrosive liquid were set up. The one was 20 C constant. The other one was called "Freeze-Thaw (hereinafter F-T)", it was recreated by a temperature cycling from 20 C to -20 C. A trapezoid profile of a cycle was used as the temperature cycle for 12 hours. The temperature of coolant was changed linearly from 20 C to -20 C, and held at -20 C during four hours. Then the temperature of coolant was changes linearly from -20 C to 20 C, and held at 20 C during one hour. Under the temperature conditions, the $FeCl_3$ solution was exposed to the temperature change with solid-liquid phase transition. Such a freeze-thawing cycle is often occurred a snow and cold prone area during a winter season.

3. Result and Consideration

Fig.1 shows the appearance of the weld interface of the corrosive test specimen of A6063/S15CK with (a)20 C constant and with (b)F-T after the tension test. Comparing (a) with (b) of Fig.1, it can be recognized that the corrosion under (a)20 C constant is larger than that of (b)F-T environment.

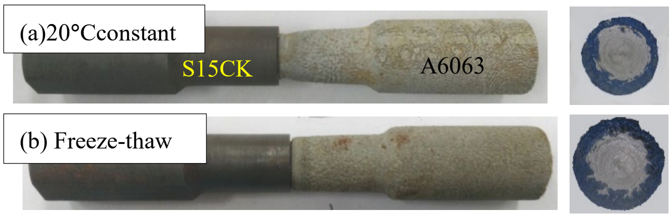

Fig.1 Appearance and fracture surface of A6063/S15CK after corrosion test for 2weeks

Fig.2 shows the cross section area, tensile strength and the roughness of the groove surface based on the each joint condition. As shown in the Fig.2, the roughness of the groove surface of (b)F-T is larger than that of (a)20 C. Since tensile strength has a proportional relation with cross section area, the tensile strength of (b)F-T ought to be larger than that of (a)20 C constant. However, it found that the magnitude relation of the both values inverted as long as looking at the results. This reverse phenomena is caused by concentration cell corrosion. It is thought that the corrosion enlarge the surface roughness which induces notch effect.

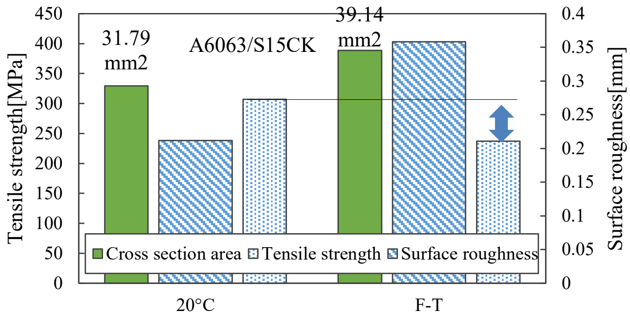

Fig.2 Comparison between 20 C and F-T in terms of tensile strength and cross section area after corrosion test for 2weeks

Fig.3 shows the tensile strength of the 3 different welded joint conditions(Best, Worse, IMC) after the corrosion test. "IMC" means that the condition produced intermetallic compounds on the welded interface. Due to the existence of IMC, which has brittleness, the joint tensile strength is dramatically low

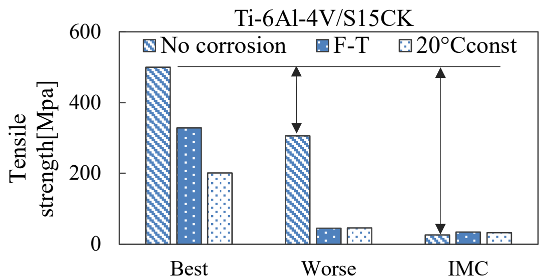

Fig.3 Comparison with the tensile stress strength of the 3 kinds of joint conditions after corrosion test for 2weeks

4. Conclusion

(1) Since the unevenness of the interface groove surface generated by concentration cell corrosion induces notch effect, it make the tensile strength of test specimen decrease.
(2) The larger the metal potential difference between metals is, the larger the reduction rate of the welded joint cross section area is.
(3) Though IMC make the joint tensile strength lower, it is effective to suppress the galvanic corrosion in the Ti-6Al-4V/S15CK test specimen.

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