Osaka University Knowledge Archive

Title	Dissimilar Metal Joining of Steel to Aluminum by Lap Joint MIG Arc Brazing(Physics, Processes, Instruments & Measurements, INTERNATIONAL SYMPOSIUM OF JWRI 30TH ANNIVERSARY)
Author(s)	Murakami, Taichi; Nakata, Kazuhiro; Tong, Hongjun et al.
Citation	Transactions of JWRI. 2003, 32(1), p. 35-37
Version Type	VoR
URL	https://doi.org/10.18910/7933
rights	
Note	

Osaka University Knowledge Archive : OUKA

https://ir.library.osaka-u.ac.jp/

Osaka University

Dissimilar Metal Joining of Steel to Aluminum by Lap Joint MIG Arc Brazing†

MURAKAMI Taichi*, NAKATA Kazuhiro**, TONG Hongjun***, USHIO Masao**

Abstract

Dissimilar metal joining of steel to aluminum, which is difficult due to the generation of the brittle intermetallic compound at the interface of the welded joint, by DC pulsed MIG arc brazing in a lap joint with the flux cored Al-Si filler wire has been investigated for the application of weight saving in automobiles. The major compounds generated at the interface between steel and weld metal were determined to be $Al_{7.4}Fe_2Si$ as the Al-Fe-Si ternary compound. The transverse tensile strength of the welded joint was 79MPa, 70 % of that of Al base metal, due to the fracture at the HAZ on the aluminum side.

KEY WORDS: (MIG Arc Brazing), (Dissimilar Metal Joining), (Aluminum), (Steel)

1. Introduction

The joining of steel to aluminum is very important from the viewpoint of weight saving transport systems such as automobiles. However, direct fusion joining is difficult because of generating a brittle intermetallic compound [1-6]. The direct solid state joining can be carried out by controlling the thickness of the intermetallic compound layer within a few micrometers at the joint interface. However, the joint shape available for these processes is extremely restricted. On the other hand, fusion welding has not been adopted due to the difficulty in controlling the composition of the fusion metal, because each metal can be easily melted by high welding heat input. This results in severe growth of the brittle intermetallic compound layer. Katayama et al. and Schubert et al. recently reported the direct fusion welding of steel to aluminum sheet using a focused laser beam for controlling both the amount of fusion metal and the joint groove shape to suppress the melting of steel sheet [7-9]. As another approach, Achar et al. reported that the thickness of the intermetallic compound layer decreased by the use of the aluminum alloy filler metal containing Si in TIG arc welding [10]. To prevent the dissolution of steel in the weld metal, arc brazing has a high potential, since it can make a continuous joint by the deposition of the fused filler metal onto the groove without the melting of the base metal. In this process, however, the oxide scale on the groove surface has a detrimental effect on the wettability of the molten metal. In conventional furnace brazing of aluminum alloy, flux is frequently used for removing the oxide scale and protecting the molten metal from the surrounding atmosphere during joining, and the flux cored wire or sheet based on Al-Si alloy is commonly used as a filler metal.

Therefore, in this study, we have selected and tried one possible joining process, the direct fusion joining of steel to aluminum for lap joints by the MIG arc welding method, so-called MIG arc brazing using flux cored Al-Si alloy wire as a consumable electrode.

2. Experimental

Cold rolled plain carbon steel sheet (SPCC) and industrial pure aluminum sheet (A1050P-H24), whose size are 150×150×2mm, were used for the lap joint welding. An aluminum sheet was lapped over a steel sheet on a copper backing plate with the thickness of 3mm. The surface of the work piece was cleaned by acetone before arc brazing. The DC pulsed MIG arc brazing was carried out using a flux cored wire of 1.6mm in diameter and argon as shielding gas at a flow rate of 15l/min. A filler wire, which was used as a consumable electrode for MIG arc brazing, was BA4047W consisting of Al-12.0%Si alloy with flux whose components were CsF, AlF_3, KF and Al_2O_3. The wire feed rate was 4.0m/min, and the mean welding current and voltage were controlled at about 100A and 17V, respectively. The welding speed was 0.4m/min. The aiming position of a MIG torch was the edge of the upper aluminum sheet.

† Received on January 31, 2003
* Post doctoral research Fellow
** Professor
*** DAIHEN Corporation

Transactions of JWRI is published by Joining and Welding Research Institute of Osaka University, Ibaraki, Osaka 567-0047, Japan

These welding conditions were decided to minimize the melting amount of steel sheet and to melt selectively the aluminum sheet.

Typical cross sections of the work piece were observed by optical microscopy. The composition of the intermetallic compound layer at the interface between steel and weld metal was determined using Electron Probe Micro Analyzer (EPMA) with ZAF correction. In addition, the distribution of the Vickers hardness at the upper aluminum sheet of the welded joint was measured. The work piece was cut off in widths of 30mm, and transverse tensile tests perpendicular to a welding direction were carried out to measure the joint tensile strength at the rate of 1mm/min.

3. Results and discussion

3.1 Macro and microstructures

Figure 1 shows the bead appearance and typical cross section of the welded joint. The upper sheet in the photo is A1050 and the lower is SPCC in Fig. 1-a). The welding was carried out with the left-right direction. A smooth weld bead with about 10mm width was made, though much spatter was generated and the work piece was covered with the flux film. The SPCC/weld metal interface keeps a straight line, because SPCC did not melt into the weld metal as shown in Fig. 1-b). Weld defects such as cracking and porosity were not observed.

Figure 2 shows a microstructure of the interface between weld metal and base metal on SPCC etched by 5% nital solution. In the weld metal, three different structures were observed; i.e., α-aluminum as a matrix, Al-Si eutectic as a network, and a plate-like structure of Al-Fe-Si intermetallic compound, which was determined to be $Al_{7.4}Fe_2Si$ by EPMA. At the SPCC/weld metal interface, an intermetallic compound layer whose average thickness was 2.5μm was formed. Most of past reports [1-3] about the welding of steel to aluminum alloy using friction, spot and resistance weldings indicated that the generated compound layers at the joint interface were Al_5Fe_2 or Al_3Fe as the binary compound. In this study, however, the generated compound layers at the interface were determined to be $Al_{7.4}Fe_2Si$ as the Al-Fe-Si ternary compound, which was the same as the intermetallic compound generated at the weld metal, because the filler wire contained 12wt%Si. At the interface of A1050/base metal, no intermetallic compound was observed, and the good adherence was obtained.

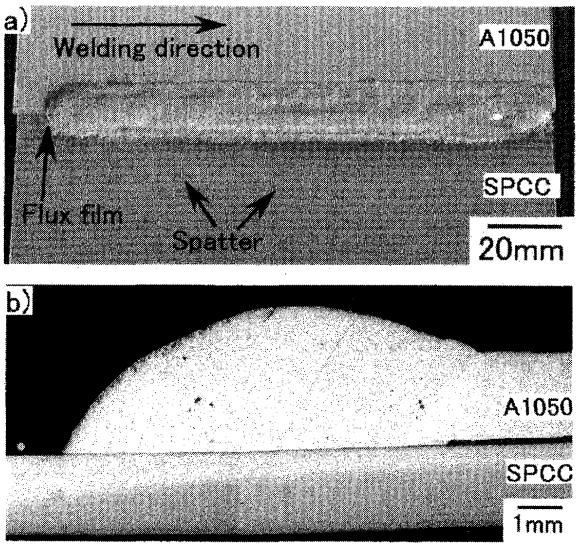

Fig.1 Weld bead appearance a) and typical cross section b) of lap joint welded specimen.

3.2 Mechanical properties

Figure 3 shows the relation between Vickers hardness and the distance from the fusion boundary of the aluminum side. The width of the heat affected zone (HAZ) was in 12mm. The Vickers hardness of the HAZ was about 28HV, corresponding to 70-80 percent of that of base metal. Figure 4 shows the tensile strength of the

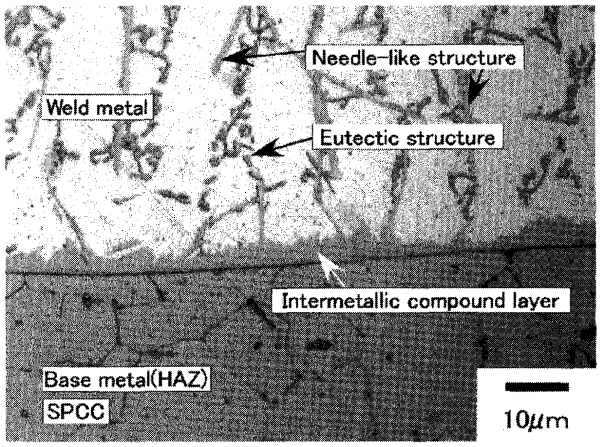

Fig.2 Microstructure of interface between weld metal and base metal on SPCC.

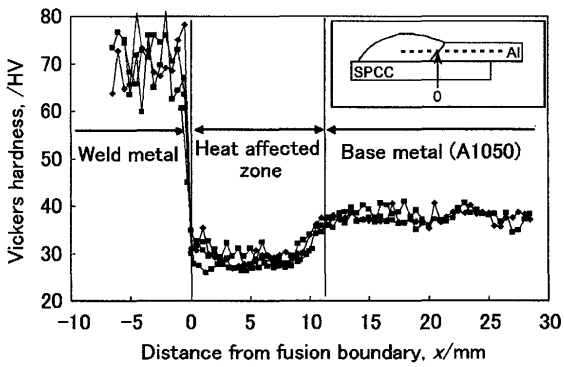

Fig.3 Distribution of Vickers hardness at upper aluminum sheet and weld metal.

welded joint and each base metal. The welded joint was fractured in the HAZ on the aluminum side, and the tensile strength was 79MPa. The tensile strengths of A1050 and SPCC were 110 and 310MPa, respectively. The tensile strength of the welded joint equaled 72 percent of that of the aluminum base metal. Consequently, it is indicated that good welded joint between aluminum and steel can be obtained by MIG arc welding.

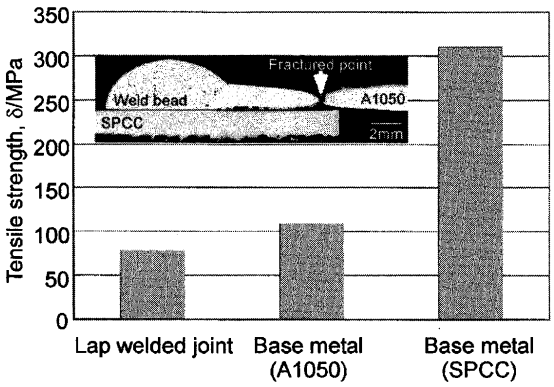

Fig.4 Tensile strength of welded joint and base metals of A1050 and SPCC with macrostructure of fractured joint.

4. Conclusions

Dissimilar metal joining of steel to aluminum by DC pulsed MIG arc brazing, in which torch aiming point was the edge of upper aluminum sheet, in a lap joint with the flux cored Al-Si filler wire at the welding speed of 0.4m/min was successfully performed, and good weldability was obtained. The generated intermetallic compound layer with the thickness of 2.5μm at the interface between steel and weld metal were $Al_{7.4}Fe_2Si$, because the filler wire contained 12%Si. The transverse tensile strength of the good welded joint fractured at HAZ in aluminum base metal was about 79MPa, which equaled to a fraction 0.7 of that of Al base metal.

References

1) T. Taka, K. Ogawa and M. Yasuyama, Welding Technique 41 (1993), 83-87 (In Japanese).
2) H. Oikawa, T. Saito, T. Yoshimura, T. Nagase and T. Kiriyama, Quarterly J. Japan Welding Soc., 14 (1996), 69-80 (In Japanese).
3) H. Ochi, K. Ogawa, Y. Suga, T. Iwamoto and Y. Yamamoto, J. Light Metal Welding & Construction, 32 (1994), 469-476 (In Japanese).
4) M. Kikuchi, H. Takeda and S. Morozumi, J. of Japan Institute of Light Metals, 34 (1984), 165-173 (In Japanese).
5) S. Elliott and E. R. Wallach, Metal Construction, 13 (1981), 167-171.
6) S. Elliott and E. R. Wallach, Metal Construction, 13 (1981), 221-225.
7) S. Katayama, R. Usui and A. Matsunawa, Proc. 5th Int. Conf. on TREND IN WELDING RESEARCH, Georgia, (1998), 467-472.
8) E. Schubert, M. Klassen, I. Zerner, C. Walz and G. Sepold, Journal of Materials Processing Technology, 115 (2001), 2-8.
9) E. Schubert, I. Zerner and G. Sepold, Proc. ICALEO '98, DESTTech Publications, Lancaster PA, (1998), 111-120.
10) D. R. G. Achar, J. Ruge and S. Sundaresan, Aluminum, 56 (1980), 291-293.