Development of Joining Technology on Aluminium and Plated Steel Sheets

by

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Synopsis

The spot welding of aluminium and plated steel sheet with insert of Al-Si foil was investigated and newly developed by using Impulsive High Current Density (IHCD). The mechanical properties of impulsive high current density spot welding joint were measured by cross tensile test and the microstructure of welded joint by this process was observed. Moreover, the effect of thickness of insert Al-Si foil on dissimilar spot welded joints were studied.

The newly developed (IHCD) joint of aluminium alloy sheet and Al-Mn plated steel sheet with insert of Al-Si foil has excellent tensile strength in cross tension test and fractured in the base metal of aluminium. By using the suitable thickness Al-Si foil under the conditions of impulsive high current density, Al-Mn plated layer is melted and squeezed out of interface and, as a result, the interface of aluminium to steel was directly joined.

1. Introduction

The establishment of reducing the automotive body's weight has been expected from energy-saving and environmental assessment. For automotive body to reduce the weigh, the point of aluminium is the most attractive material, which has more deformability and recyclability to the other materials, for example magnesium and plastic and so on. On the other hand, aluminium has been inferior in weldability, cost and deformability to steel, which has been mainly used automotive bodies. It is necessary to reduce to develop the dissimilar joining technology of aluminium and steel, in order to reduce the weight of the automotive body. As for the dissimilar joint of aluminium and steel, there are some studies of solid state bonding, friction, explosive[1] and diffusion welding[2]. It is well known that the Fe-Al intermetallic compounds were formed at faying zone of aluminium and steel sheet resulting in the deterioration of strength. Recently, the resistance spot welding method of aluminium and steel with insert of aluminium clad steel sheet , which was produced by roll bonding, was proposed[3),4)]. However, the resistance welding method of aluminium and steel were not studied enough. In this report, the impulsive high current density spot welding method of aluminium and plated steel sheet with insert of Al-Si foil was studied. The microstructure and tensile strength of dissimilar joint using this newly developed process was clarified.

2. Materials and Experimental Procedure

Aluminium alloy(JIS A5052,thickness of 1.0mm) and Al-30mass%Mn plated steel (thickness of 0.8mm)were used as base materials and Al-11mass% Si (thickness of 3～100μm)were used as an insert metal. The chemical compositions of materials were shown in **Table 1**. Aluminium alloy and Al-Mn plated sheet with insert of Al-Si foil were high current spot welded using condenser type spot welder(**Fig. 1**). The current wave shape of this welding conditions were shown in **Fig 2**. Welding time(Tp) and welding current(Ip) are defined as **Fig. 2**. The spot welding conditions are listed in **Table 2**.

Table 1 Chemical compositions of materials used (mass%)

Materials	Fe	C	Mn	P	S	Nb	Ti	Al
Steel	Bal.	0.002	0.15	0.015	0.003	<0.001	0.052	0.038
Materials	Al	Mg	Si	Mn	Ti	Cu	Fe	Cr
A5052	Bal.	2.72	0.03	0.01	0.04	0.33	0.09	0.04
Al-Si foil	Bal.	—	11.3	0.02	0.01	—	0.21	—

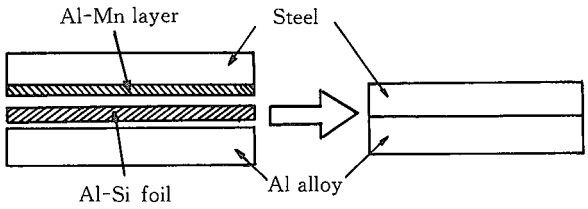


Fig. 1 Schematic illustration of aluminium and Al-Mn plated steel sheet with insert of Al-Si foil

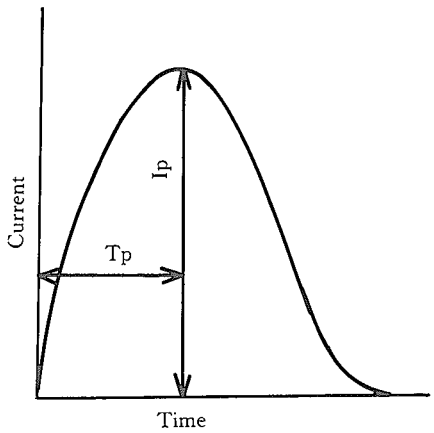


Fig. 2 Wave shape of weld current

Table 2 Welding conditions

Welding current (Ip)	30~65kA
Welding time (Tp)	1.3ms
Welding force	1 960N
Electrode configuration	CF-type ϕ 4mm
Electrode material	Cu-1%Cr

The mechanical properties of dissimilar spot welded joint of aluminium to Al-Mn plated steel sheet or non plated steel sheet with or without insert of Al-Si foil were measured by using cross tension test, and the microstructure by this process was observed using optical microscope and scattering electron microscope (SEM) and electron probe microscope analysis (EPMA).

3. Result and Discussions

Figure 3 shows fracture strength of dissimilar

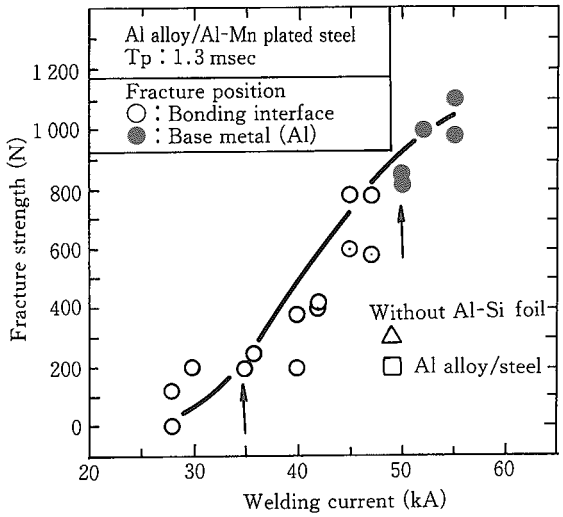
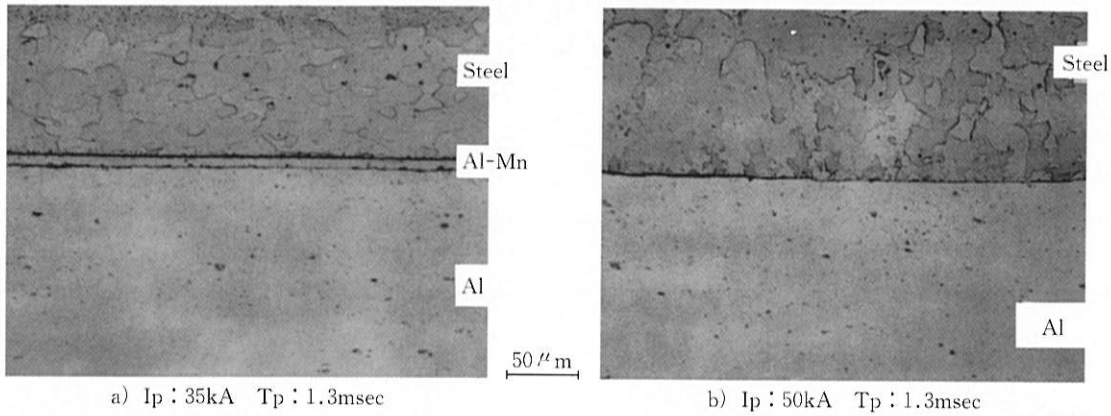


Fig. 3 Fracture load in cross tensile test of developed joint of Al alloy and Al-Mn plated steel sheet with insert of Al-Si foil

spot welded joint by this process. The IHCD spot welded joint of aluminium and Al-Mn plated steel sheet with insert of Al-Si foil had excellent tensile strength and fractured in the base metal of aluminium. In case of joining aluminium alloy sheet to non plated steel with insert of Al-Si foil and aluminium alloy sheet to Al-Mn plated steel sheet without Al-Si foil, the IHCD joints had inferior strength and fractured at interface. Al-Si foil and Al-Mn plated layer were necessary for maintaining excellent tensile strength. The nugget of aluminium and steel was not deformed at this combination. As can be seen in **Fig. 4**, in case of inferior strength with welding current of 35kA, Al-Mn plated layer were observed at faying zone and it is believed that Al-Si foil was melted and squeezed during joining process. On the other hands in the case of excellent strength with welding current 50kA, both Al-Si foil and Al-Mn plated layer were melted and squeezed out laying area during this process. Aluminium and steel were directly joined. Both of Mn-rich and Si-rich area were not observed at interface of aluminium and steel by EPMA line analysis as shown in **Fig. 5**.



a) Ip : 35kA Tp : 1.3msec b) Ip : 50kA Tp : 1.3msec

Fig. 4 Microstructure of impulsive high current density spot welded interface of Al alloy and Al-Mn plated steel with insert of Al-Si foil

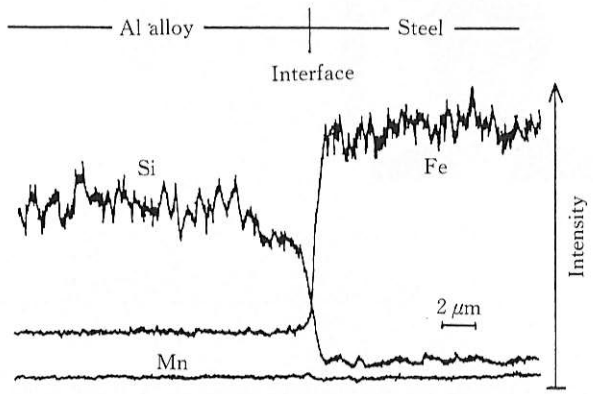


Fig. 5 Disribution of Si and Mn content by EPMA analysis at interface of developed joint

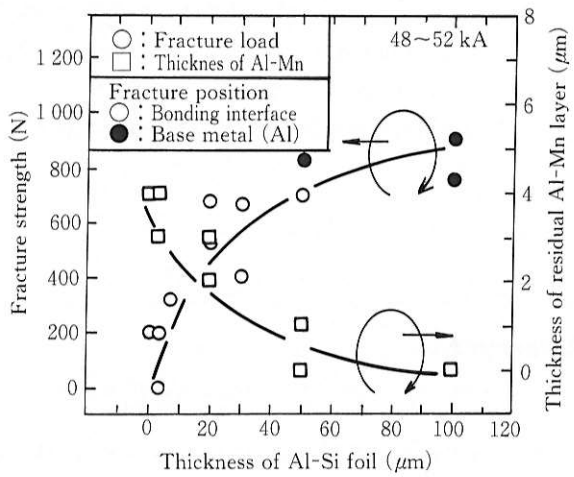
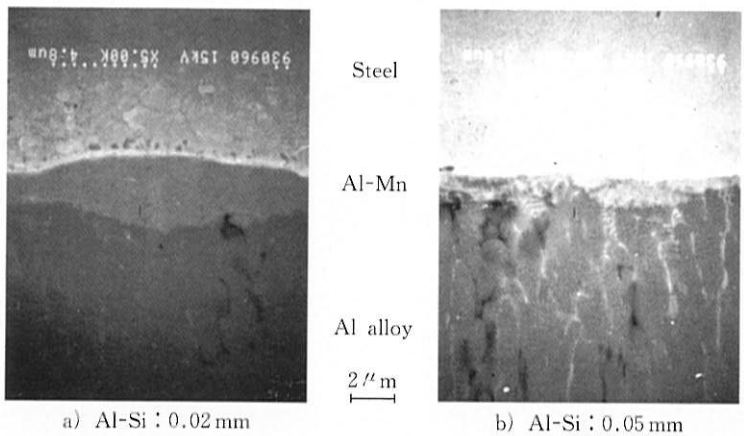


Fig. 6 Effect of Al-Si foil thickness on fracture strength of welded joints and thickness of residual Al-Mn layer at bonding interface

Fe-Al intermetallic compound were not observed at this directly joined interface by SEM observation(× 10 000). These results indicated that both Al-Si foil and Al-Mn plated layer were necessary for directly joining of aluminium and steel interface as a result of melting and squeezing out during this process.

Effect of Al-Si foil thickness on fracture load and thickness of residual Al-Mn layer at center of bonding area was shown in **Fig. 6**. Thickness of residual Al-Mn layer decreased as thickness of Al-Si foil increased. On the other hand, the tensile strength of the newly developed joints increased according to thickness of Al-Si foil. As seen in **Fig. 7**, in the case of over 50μm, the IHCD joints were fractured in the base metal of aluminium and for-



a) Al-Si : 0.02 mm b) Al-Si : 0.05 mm

Fig. 7 Microstructure of IHCD spot welded interface of aluminium alloy and Al-Mn plated steel with insert of Al-Si foil

med directly aluminium and steel interface. In other words, in the case of remained Al-Mn plated layer at the interface, the developed joints had inferior tensile strength.

It is considered that the function of Al-Si foil is concentrating resistance heating at interface, and that of Al-Mn plated layer is defending contact of aluminium and steel until the both of interface is heated at respective suitable temperature.

4. Conclusion

The major conclusions obtained in this investigations were as follows;

(1) The impulsive high current density spot welded joint of aluminium alloy and Al-Mn plated steel sheet with insert of Al-Si foil has excellent tensile strength and fractured in the base metal of aluminium.

(2) Under the conditions of obtained excellent strength, both Al-Si foil and Al-Mn plated layer were melted and squeezed out at faying zone during joining process, and therefore, aluminium and steel were directly joined.

(3) By using the suitable thickness of Al-Si foil (>50μm), resistance heat was concentrated at interface, as a result, Al-Mn plated layer were melted and squeezed.

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