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Feasibility of Using TIG Welding in Dissimilar Metals between Steel/Aluminum Alloy

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Abstract: Problem statement: Currently, in order to suppress intermetallic reaction layer formation during dissimilar metals welding between steel/aluminum alloy, only laser beam welding as self-brazing technique has been applied. However, TIG welding process might be one of welding process candidate for joining dissimilar metals welding between steel/aluminum alloys due to its capability in joining thin section. In the present study, the feasibility of application of TIG welding process in joining dissimilar metals between steel/aluminum alloy was evaluated. **Approach:** In order to realize the feasibility of TIG welding process, bead on the steel sheet experiment and dissimilar metals welding experiment was carried out. **Results:** From bead on the steel sheet experimental results, TIG welding could produce the partial penetration welding in 1 mm thickness steel sheet. In dissimilar metals welding experiment, TIG welding process as a self-brazing technique could successfully join dissimilar metal between steel and aluminum alloy. Moreover, the load resistance of bonded zone of dissimilar metals joints was higher than the load resistance of A1100 aluminum alloy after welding. **Conclusion:** These results indicated that TIG welding process is feasible to be dissimilar metals welding candidate for joining steel/aluminum alloy.

Key words: Dissimilar metal joining, TIG welding, steel, aluminum alloy

INTRODUCTION

It has been known that the difficulty of dissimilar metals joining between steel and aluminum alloy is caused with the brittle intermetallic reaction phase formation. In order to suppress the formation of intermetallic reaction phase, self-brazing technique, which the molten zone of steel was controlled to be a partial penetration during lap-joint welding between steel/aluminum alloy as shown in Fig. 1, was used in many researches (Borrisutthekul *et al*., 2007; Miyashita *et al*., 2005; Lee *et al*., 2005; Lee and Kumai, 2006; Rathod and Kutsuna, 2004). TIG welding is suitable welding process for joining thin section. It is one of the possible welding processing for joining dissimilar metal between st/eel/aluminum alloys by using self-brazing technique due to its possibility to produce partial penetration weld in steel sheet. However, few researches were done in order to investigate the feasibility of using TIG welding process in joining steel and aluminum alloy by using self brazing process. Thus, in the present study, the feasibility study in production partial penetration in steel by TIG welding was done firstly in order to examine the feasible in using self-brazing technique of TIG welding. Then, the feasibility study of using TIG welding in welding of dissimilar metals between steel and aluminum alloy was carried out.

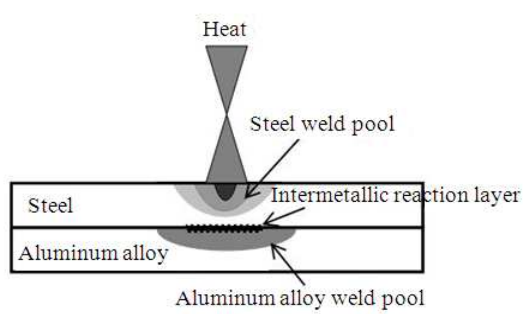

Fig. 1: Schematic of the interface during dissimilar metals welding between steel and aluminum alloy

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Table 1: Chemical compositions of materials

	Chemical composition (wt%)							
Material	Fe	C	Mn	Cu	Si	Mg	Zn	Al
1100 Al alloy	0.581	-	-	0.073	0.110	<0.001	0.018	99.220
Steel	99.51	0.077	0.277	<0.005	0.016	0.001	-	0.025

Table 2: Mechanical properties of materials

	Mechanical properties		
Material	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
1100 aluminum alloy-H12	105	110	12
Steel	275	380	21

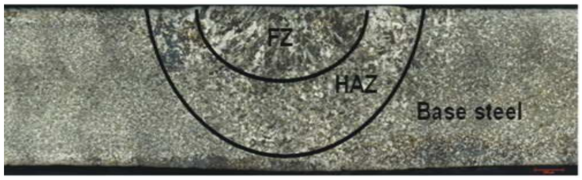

Fig. 2: The macrostructure of steel weld with electrical current of 45 ampere current and 0.65 m min^{-1} of welding speed

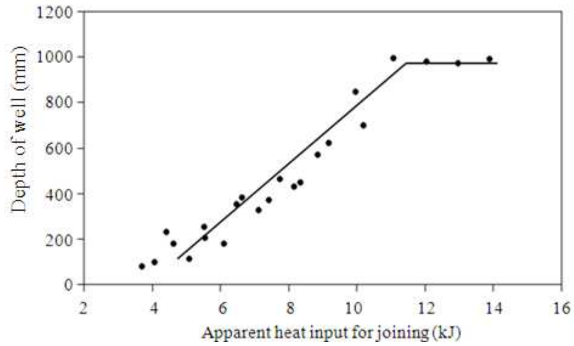

Fig. 3: The relation between heat input and weld pool depth

MATERIALS AND METHODS

Materials used: The 1 mm thick hot roll steel sheet (steel) and 0.8 mm thick 1100 aluminum alloy-H12 sheet (aluminum alloy) were used. Their chemical compositions and mechanical properties are shown in Table 1 and 2, respectively. Both steel and aluminum alloy were prepared in size of 85×65 mm.

Bead on steel sheet: The bead on steel sheet experiment was carried out in order to study the feasibility to produce the partial molten penetration in 1 mm steel sheet, which is the basics requirement of application of self-brazing technique. The experiment was started by immerging steel sheet in 12% HCl for 2 min at 80°C in order to remove oxide layer formed during hot rolling process. The bead on the steel sheet was done by TIG welding process with welding speed of 0.55, 0.60 and 0.65 m min^{-1}. Welding current were varied from 20-75 A. The Direct Current Electrode Negative (DCEN) was used in this study. The arc distance, electrode type, electrode size and electrode tip angle was 2.4 mm, EWTh-2, 3.2 mm in diameter and 60° respectively. Pure argon gas with 8 L min^{-1} was used for prevention the oxidation of molten steel. The macroscropic observations were carried out in order to obtain the depth of weld.

Figure 2 shows the macroscropic observation of steel weld pool obtained with electrical current of 45 A and 0.65 m min^{-1} of welding speed. From the Fig. 2, it was found that the partial penetration of molten zone of steel sheet could be obtained by TIG welding process.

Figure 3 shows depth of weld obtained with various apparent heat input for joining. From Fig. 3, it was found that many welding conditions could be produced the partial penetration welding in 1.0 mm thickness steel sheet. Moreover, it was found that the depth of weld was increased when heat input was increased. Thus, it could be referred that TIG welding process is possible to join dissimilar metals by self-brazing process in limiting welding heat input.

RESULTS AND DISCUSSION

Dissimilar metals welding between steel/aluminum alloy: Although, TIG welding process showed the potential to be the welding process for joining dissimilar metals between steel/aluminum alloy as discussion in bead on the steel sheet section, it is not confirmed that the dissimilar metals joint has well quality. Thus, in dissimilar metals welding between steel/aluminum alloy section, TIG welding together with self-brazing technique in joining dissimilar metals was investigated.

The experiment was started by removing oxide layer in steel sheet by dipping steel sheet in 12% HCl for 2 min at 80°C After that both steel and aluminum alloy was polished and cleaned with #180 emery paper and ethanol, respectively. The TIG lap joint welding configuration with steel top sheet was used as shown in Fig. 4. The arc distance, electrode size and electrode type were 2.4, 3.2 mm in diameter and EWTh-2,

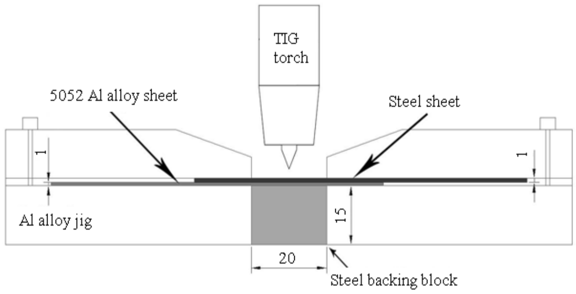

Fig. 4: Welding configuration used

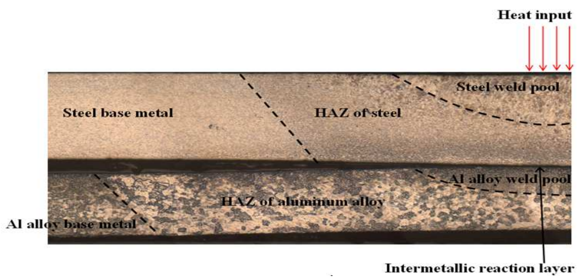

Fig. 5: Overview of the joint

respectively. The Direct Current Electrode Negative (DCEN) was applied. Argon gas with 8 L min^{-1} was used for shielding the welding specimens. Welding speeds of 0.55, 0.60 and 0.65 m min^{-1} were used. In this study, welding current was varied in order to obtain the joint where steel and aluminum alloy were not directly mixed during welding. After welding the tensile shear test and microstructure observation were carried out.

Figure 5 shows an example of half view of the joint between steel and aluminum alloy. From Fig. 5, it could be seen that TIG welding could make the dissimilar metals joint between steel/aluminum alloys by self-brazing technique. Moreover, different zones in joining region were found; steel weld pool, HAZ of steel, steel base metal, intermettallic reaction layer, aluminum alloy weld pool, Heat Affected Zone (HAZ) of aluminum alloy and aluminum alloy base metal.

Figure 6 and 7 show intermetallic reaction layer formed at interface between steel and aluminum alloy under various welding speeds at constant electrical current used and under various electrical currents at a constant welding speed, respectively. From both Fig. 6 and 7, it was found that thickness of intermetallic reaction layer was decreased with increasing welding speed and with decreasing electrical current. Figure 8 shows the thickness of intermetallic reaction layer (IMP) under various apparent heat input for joining.

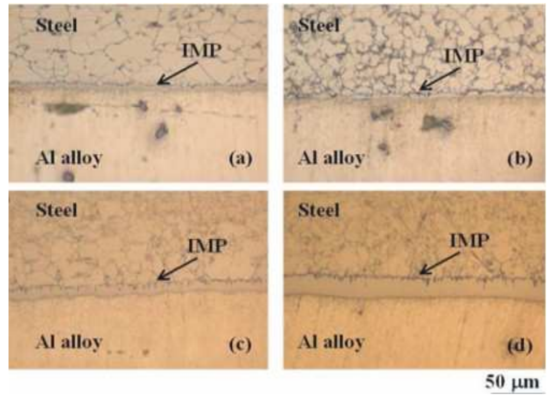

Fig. 6: Intermetallic reaction layer obtained at welding speed of 0.65 m min^{-1} and (a) 90; (b) 110; (c) 130; (d) 150 A of electrical current used

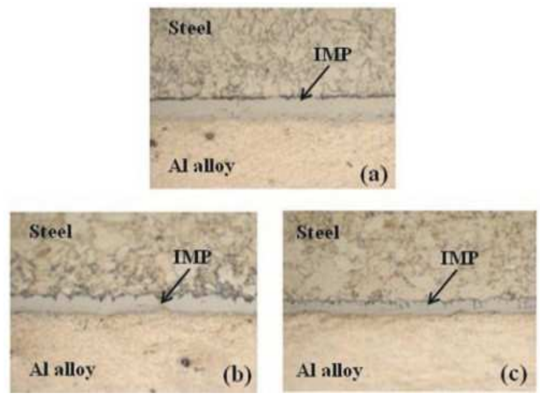

Fig. 7: Intermetallic reaction layer obtained at 130 A and welding speed of (a) 0.55 m min^{-1}; (b) 0.60 m min^{-1}; (c) 0.65 m min^{-1}

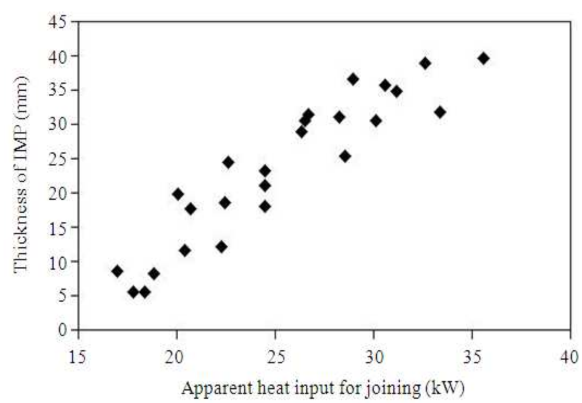

Fig. 8: The relationship between thickness of intermetallic reaction layer and apparent heat input for joining

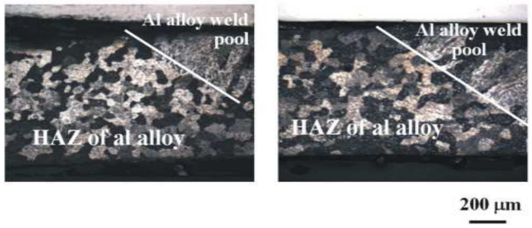

Fig. 9: HAZ of aluminum alloy obtained with 0.65 m min^{-1} of welding speed and (a) 100 A of electrical current; (b) 130 A of electrical current

It was found that intermetallic reaction layer thickness was increased with increasing apparent heat input for joining. From these results, if the joint could be produced at lower apparent heat input for joining, thinner intermetallic reaction layer could be formed.

From Fig. 5, it also was found that microstructures in HAZ of aluminum alloy and aluminum alloy base metal were different. The microstructure of HAZ of aluminum alloy was coarser compared to the base metal. It is known that the aluminum alloy used in this study can be strengthened only by work hardening. The deformed microstructure is ready to recrystallize and grow when temperature is increased. Thus, when the HAZ of aluminum alloy was heated up higher than recrystallization temperature and grain growth temperature, the deformed microstructure was recrystallized and followed by growth, as shown in Fig. 5.

Figure 9 shows the microstructure in HAZ of aluminum alloy under 0.65 m min^{-1} of welding speed and two electrical current used. From Fig. 9 it was found that the microstructure was slightly coarser when using higher electrical currents, which corresponded to higher apparent heat input for joining. Thus, it can be concluded that when using lower apparent heat input for joining, the finer grain in the HAZ of aluminum alloy is obtained.

Figure 10 shows the failure load of all dissimilar metals joints obtained in this study. From Fig. 10, it was found that failure load of the joints was in the range of 500-800 N, which were lower than that of base metal, about 1090 N. Moreover, it was found that the failure load slightly decreased with increasing apparent heat input for joining.

Figure 11 shows the fracture path of the joint which was common all the joints. From Fig. 11, it could be seen that the fracture path of the specimen was through the HAZ of aluminum alloy. According to microstructural observation and tensile-shear test results, it could be indicated that the weakest zone of joint was HAZ of aluminum alloy, which was due to the grain growth of aluminum alloy at HAZ.

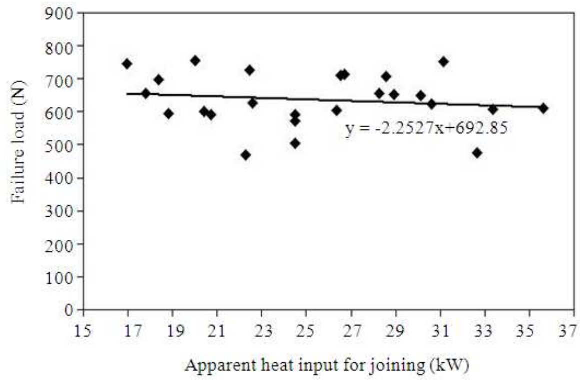

Fig. 10: The relationship between failure load and apparent heat input for joining

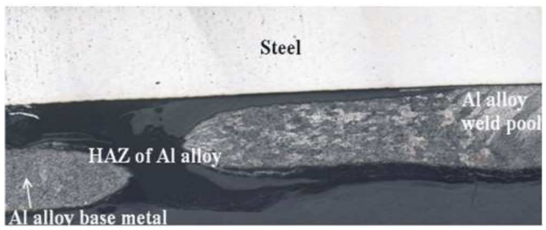

Fig. 11: Fracture part in joint with 0.65 m min^{-1} of welding speed and 165 A of electrical current used

Moreover, higher apparent heat input for joining results in coarser structure of aluminum alloy at HAZ, which affects to decrease of strength of the HAZ of aluminum alloy as realized in slightly decreasing of load resistance of joint in Fig. 10.

CONCLUSION

From above results, it could be referred that TIG welding process could produce the partial penetration welding in 1 mm thickness steel sheet, which indicated its feasibility in applying together with self-brazing technique. Moreover, TIG welding as a self-brazing technique could successfully join steel and aluminum alloy. The load resistance of bonded zone, intermetallic reaction layer zone of joint, was higher than that of A1100-H12 aluminum alloy after welding. The lower load resistance of joint compared with base A1100-H12 aluminum alloy was caused by the grain growth during welding. Moreover, it is found that using higher heat during TIG welding resulted in thicker intermetallic reaction layer and coarser microstructure in HAZ of aluminum alloy. The coarser microstructure at HAZ of aluminum alloy was main reason of lower of load resistance of aluminum alloy at heat affected zone.

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