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Effects of Aluminium Alloy Surface Preparation in TIG Dissimilar Metals Welding between Mild Steel and 5052 Aluminium Alloy

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In the present study, effects of aluminium alloy surface preparation were investigated in TIG welded dissimilar metal joints of mild steel and 5052 aluminium alloy. This research aimed to clarify the necessary of aluminium alloy surface preparation prior to welding. In the experiment, the welded specimens were classified into two categories according to surface preparation conditions, which are i) with oxide layer removal and ii) without oxide layer removal. Experimental results showed that surface preparation condition of aluminium alloy affected thickness and width of intermetallic reaction layer, which indirectly resulted in the load resistance of the joints. Finally, it could be indicated that the surface preparation by removing oxide layer prior to welding was significantly required.

Keywords: *Dissimilar metals joining, TIG welding, steel, aluminium alloy, surface preparation.*

1. Introduction

It has been referred that the surface of specimen to be welded is covered by oxide layer. The oxide layer on such a surface influences weldability, and integrity of joint. Before welding, the oxide layer has generally been recommended to be removed. Wagner and et.,al., indicated that the oxide on steel surface did not affect weldability and integrity of dissimilar metal joining between steel and aluminium alloy joint. It was due to that molten aluminium could reduce iron oxide on the steel surface. However, no publications about the effects of aluminium alloy surface preparation on the quality of dissimilar joining between steel and aluminium alloy has been discussed. Thus, in the present study, effects of aluminium alloy surface preparation were investigated in TIG welded dissimilar metal joints of mild steel and 5052 aluminium alloy in order to clarify the necessary of aluminium alloy surface preparation prior to welding.

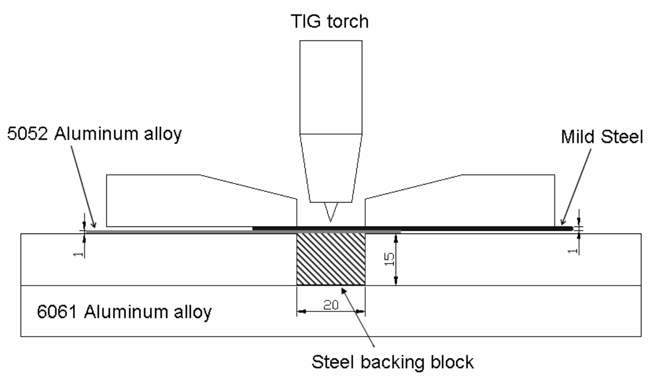

Fig. 1: Welding configuration used

2. Materials and Experimental Procedures

Mild steel and A5052 aluminium alloy plates were used in this study with their chemical compositions and mechanical properties being shown in Table 1 and 2, respectively. The plate dimensions of both metals were 85×65×1 mm^3. Prior to TIG welding, the mild steel plate was dipped in hot acid in order to remove thick oxide layer formed during hot-rolling process. After that, the mild steel plate was polished on both sides of specimen surface. In case of aluminium alloy plate, two surface preparation conditions were employed. For the first condition, designated as oxide layer removal condition, aluminium alloy surface was polished using a #180 emery paper at faying surface and cleansed with ethanol. For the second condition, only cleaning of aluminium alloy surfaces by ethanol was carried out. After surface preparation, welding of dissimilar metals was done using a TIG welding technique. A lap-joint weld configuration with steel being a top plate was used as shown in Fig. 1. The welding parameters, which are diameter of the EWTh-2 tungsten electrode (DCEN, 3.2 mm), arc distance (2.4 mm), electrode tip angle (60°) and argon shield flow (8 $L.min^{-1}$) were utilized. The welding speeds used were 0.55, 0.60 and 0.65 $m.min^{-1}$. The welding current was varied from 90-160A in order to obtain the self-brazing joint. After welding, microstructure observation, tensile shear test and fractography were carried out.

Table 1

Chemical compositions of materials

Materials	Al	Si	Fe	Cu	Mn	Mg
Steel	0.025	0.016	Bal.	< 0.005	0.277	0.001
5052 Al alloy	Bal.	< 0.25	< 0.40	< 0.10	0.15 - 0.35	2.2 - 2.8

Table 2

Mechanical properties of materials

Materials	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
Steel	275	380	21
5052 Al alloy	100	213	24

3. Results and discussion

Figure 2 shows the example of macrostructures of dissimilar metal joints between mild steel and aluminium alloy obtained from this study. It was clearly seen that the joints could be achieved by a self-brazing mechanism, which was independent on aluminium alloy surface preparation conditions. Also, seven joining zones including a molten pool of steel, steel HAZ, steel base metal, molten pool of aluminium alloy, aluminium alloy HAZ, aluminium alloy base metal and intermetallic reaction layer zone were observed. It was later found that the intermetallic reaction layer zone and aluminium alloy HAZ are the key joining zones which dominantly affected the load resistance of the joint according to the tensile shear test. It is considered that the load resistance of aluminium alloy HAZ should not be affected by surface preparation conditions. However, the aluminium alloy surface preparation might effect to formation of intermetallic reaction layer. Ref. [3], has shown that thickness and width of the intermetallic reaction layer formed during TIG dissimilar metals welding between steel/Al alloy influenced the load resistance of the joint. Thus, in later section effects of surface preparation on thickness and width of intermetallic reaction layer were discussed.

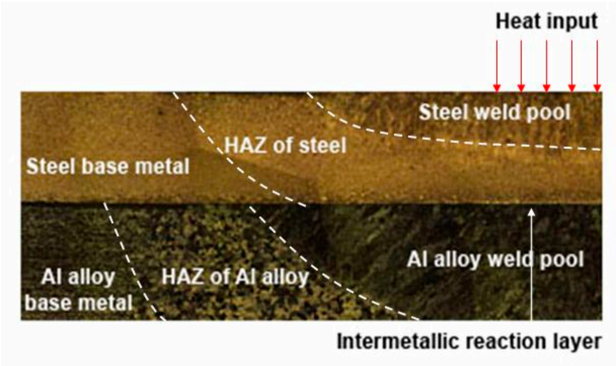

Fig. 2: Overview of the joint

Independence of oxide layer removal, there exhibit the intermetallic reaction layers formed at mild steel and aluminium alloy interface, when the joints were prepared at either constant welding current/various welding speed or constant welding speed/various welding current as observed in Figs. 3 and 4 respectively. The thickness of intermetallic reaction layer was found to reduce with increasing welding speed and decreasing electrical current. Furthermore, it seems that when the oxide layer was removed, the intermetallic reaction layers were measured to be thicker than those formed without oxide layer removal. The relationship between heat input and the thickness of intermetallic reaction layer is demonstrated in Fig. 5 while Fig. 6 illustrates the relationship between heat input and the width of intermetallic reaction layer. It could be clearly seen that in case of oxide layer removal condition, both thickness and width of intermetallic reaction layer were larger than those observed in joints without oxide layer removal at particular heat input levels. It might be caused by high wettability of molten aluminium alloy on mild steel, which led to increase both thickness and width of intermetallic reaction layer.

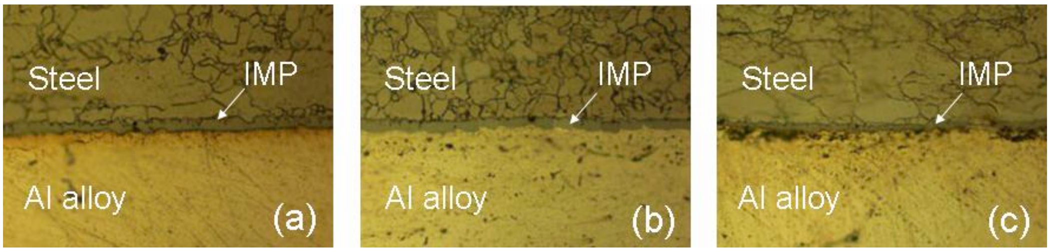

Fig. 3: Intermetallic reaction layer (IMP) observed from the joint without oxide layer removal at 110 A and welding speed of (a) 0.55 m min^{-1}, (b) 0.60 m min^{-1} , and (c) 0.65 m min^{-1}

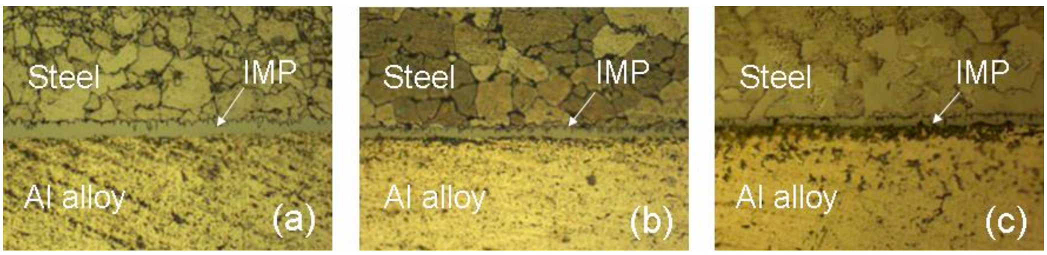

Fig. 4: Intermetallic reaction layer (IMP) observed from the joint with oxide layer removal at 110 A and welding speeds of (a) 0.55 m min^{-1}, (b) 0.60 m min^{-1} , and (c) 0.65 m min^{-1}

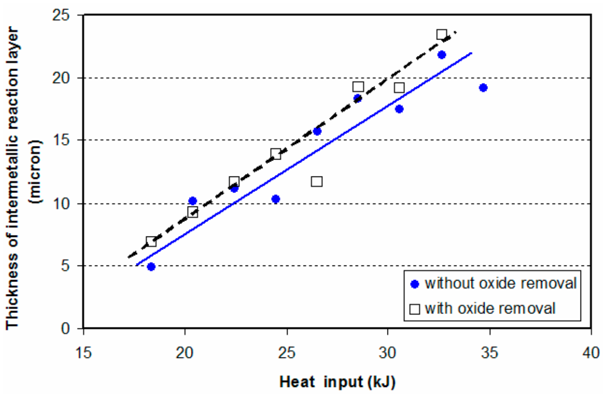

Fig. 5: Relationship between heat input and thickness of intermetallic reaction layer (IMP)

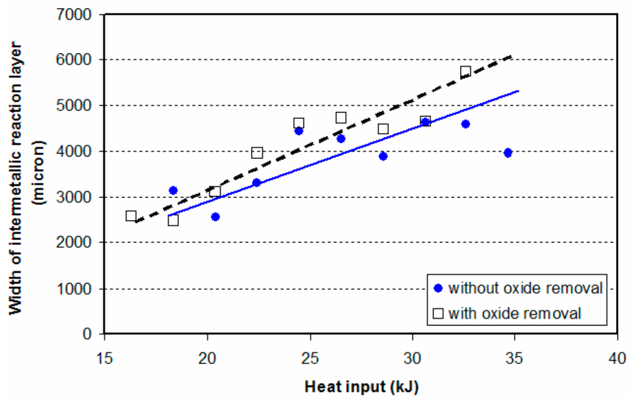

Fig. 6: Relationship between heat input and width of intermetallic reaction layer (IMP)

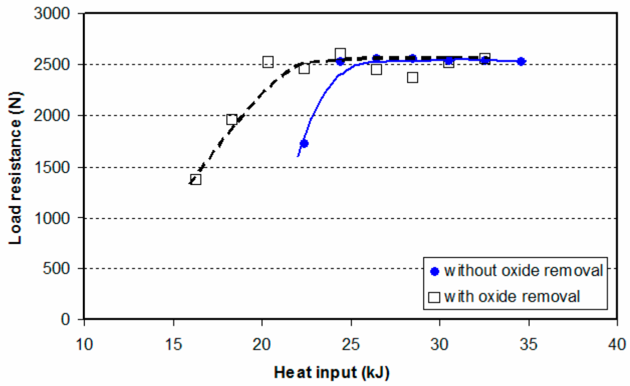

Fig. 7: Relationship between heat input and load resistance of the joint at welding speed 0.60 $m.min^{-1}$

Fig. 8: Fractured part in TIG joint welded using 28.5 kJ of heat input.

Figure 7 shows the relationship between load resistance of the joint and heat input used in TIG welding of mild steel and aluminium alloy in both with/without oxide layer removal conditions. The load resistance of the joints increased with increasing heat input and then reached the maximum value at about 2500 N, which was comparable to the strength (Load) of aluminium alloy HAZ as the evident was shown in Fig. 8. According to Fig. 7, it was clearly seen that the load resistance of joint prepared with oxide layer removal increased to the maximum value at the lower heat input level than those observed from the joint prepared without oxide layer removal. This was due to the larger weld width in case of joint prepared with oxide layer removal in comparison to those prepared without oxide layer removal. The larger weld width in turn imparted the increasing load resistance of the intermetallic reaction layer, therefore, yielding greater load resistance of dissimilar metal joint.

4. Conclusion

According to above results, surface preparation of aluminium alloy plates affected the thickness and width of intermetallic reaction layer, which directly influenced the load resistance of the joints. Cleaned aluminium alloy faying surface provided high wettability of molten aluminium alloy on the mild steel surface. Moreover, cleaned faying surface of aluminium alloy provided suitable condition for joining.

Acknowledgement

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