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Effects of TIG Welding Parameters on Dissimilar Metals Welding between Mild Steel and 5052 Aluminum Alloy

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In the present study, the effects of TIG welding conditions such as welding speed, arc length and welding current on the quality of steel/aluminum alloy dissimilar joint were examined. The obtained information is beneficial for extending the limitation of TIG welding in dissimilar metal joining between steels and aluminum alloys. Experimentally, the varied welding parameters involved welding speed, arc length and current used. It was found that at particular apparent heat input, increasing welding speed and current did not significantly affect the weld width and the thickness of intermetallic reaction layer. Moreover, using improper arc length resulted in increasing welding width and limiting welding windows, but it was not found to be a factor influencing the thickness variation of the intermetallic reaction layer. Finally, the variation of welding speed and arc length has the influence on the strength of intermetallic reaction layer.

Keywords: *Dissimilar metals joining, TIG welding, Welding parameters, steel, A5052 aluminum alloy*

1. Introduction

In production of eco-vehicle, automotive maker has applied the hybrid structure technology to reduce weight of vehicle, which is the effective method to reduce the emission of green house effects gas of vehicle during driving. In using hybrid structure, joining between automotive parts made by various metals has been encountered. Recently, many research works concerned with dissimilar metals joining, especially between steel and aluminum alloy, have been carried out [1-5]. One of potential welding processes for joining dissimilar metals is TIG welding process [1]. However, TIG welding process could produce the well dissimilar metals joint incase of joining thin dissimilar metals sheet. In order to extend the limitation of TIG welding in joining thicker dissimilar metals sheet, understanding of effects of welding parameters on the joining quality has been important. Thus, in this study, effects of welding speed, welding current, and arc length on size of welding windows, intermetallic reaction layer (IMP) formation, as well as failure load of joint were investigated.

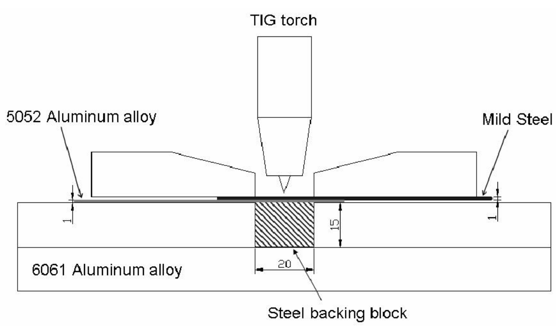

Fig. 1: Welding configuration used

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Table 1

Chemical compositions of materials

Materials	Al	Si	Fe	Cu	Mn	Mg	Cr
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	< 0.1

Table 2

Mechanical properties of materials

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

2. Materials and Experimental Procedures

Mild steel and A5052 aluminum 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. Before welding, steel and aluminum alloy surface were cleaned. After cleaning, dissimilar metals welding between steel and aluminum alloy was carried out. A lap-joint weld configuration with steel being a top plate was used as shown in Fig. 1. The welding mode, the diameter of the EWTh-2 tungsten electrode, the electrode tip angle, and the flow rate of argon gas were DCEN, 3.2 mm, 60°, and 8 $L.min^{-1}$, respectively. The arc lengths used were 1.6, 2.4, and 3.2 mm. The welding speeds used were 0.55, 0.60 and 0.65 $m.min^{-1}$. Welding current was varied from 90-190 A in order to obtain the self-brazing joint. After welding, the tensile shear test, and microstructure observation were carried out.

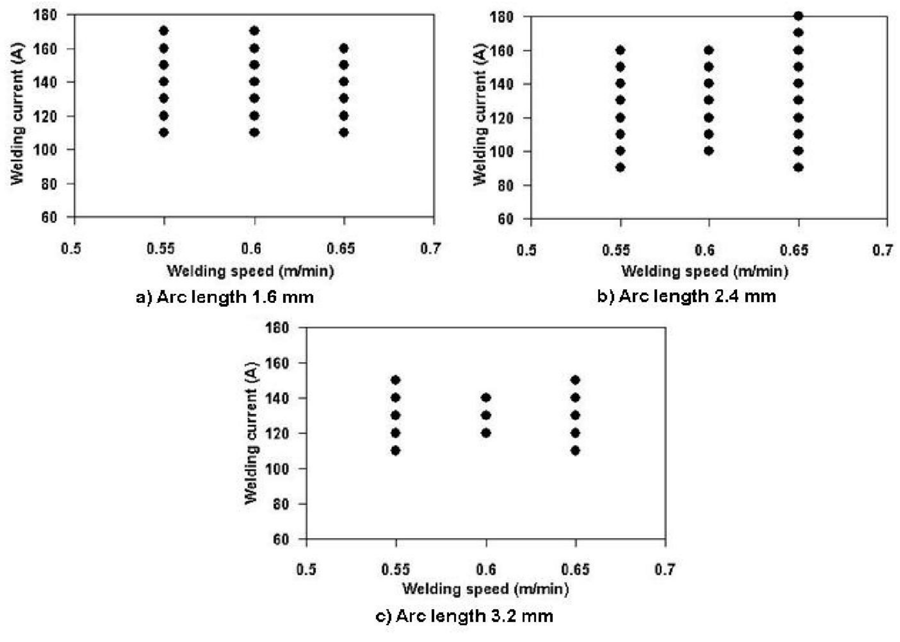

Fig. 2: Weldable conditions obtained with various arc lengths

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3. Results and discussion

3.1 Effect of arc length on the size of welding windows

Based on welding conditions used in the study, only effect of arc length on the size of welding windows could be discussed. In this study, the size of welding windows could be evaluated with the number of weldable conditions. Large number of weldable condition means large size of welding windows. Figure 2(a)-2(c) show the weldable conditions in case of using 1.6, 2.4, and 3.2 mm of arc lengths, respectively. Comparing Fig. 3(a)-3(c), it could be clearly seen that the number of weldable conditions in case of using 1.6 mm and 3.2 mm of arc lengths were smaller than that of 2.4 mm of arc length. During welding, the arc was difficult to start when using 1.6 and 3.2 mm of arc lengths compared with 2.4 mm of arc length. According to results, it could be referred that arc length significantly affected to size of welding windows.

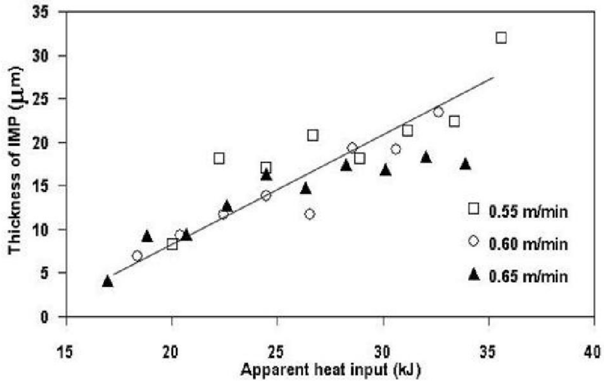

Fig. 3: Relationship between apparent heat input and thickness of intermetallic reaction layer with various welding speeds at 2.4 mm of arc length

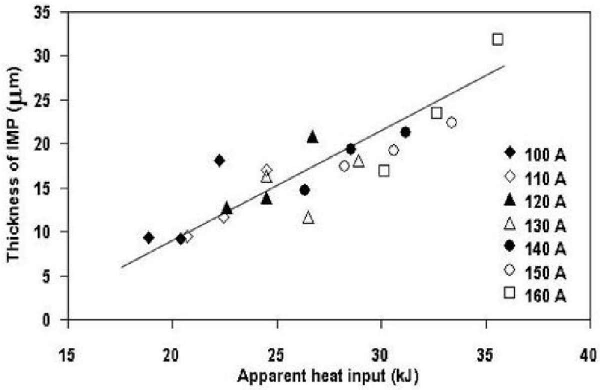

Fig. 4: Relationship between apparent heat input and thickness of intermetallic reaction layer with various welding currents at 2.4 mm of arc length

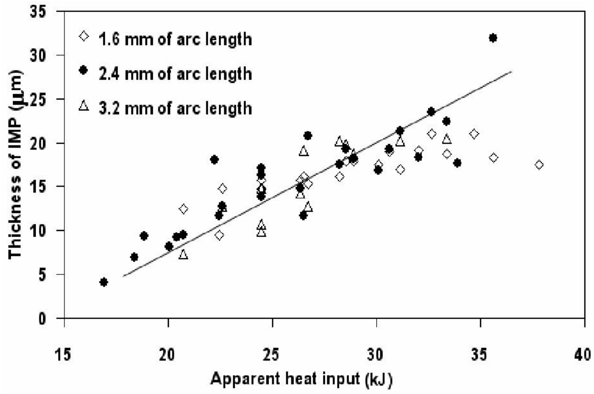

Fig. 5: Relationship between apparent heat input and thickness of intermetallic reaction layer with various arc lengths

3.2 Effect of welding parameters on intermetallic reaction layer thickness

Figure 3-5 show the relationship between apparent heat input and intermetallic reaction layer thickness with various welding speeds, various welding currents, and various arc lengths, respectively. From Fig. 3-5, it was realized that increasing apparent heat input affected to increase thickness of intermetallic

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reaction layer. Moreover, no effect of variation of welding speed, welding current and arc length at particular apparent heat input on thickness of intermetallic reaction layer was found. Although, it was believed that they should affect to thickness of intermetallic reaction layer. The acceptable reason for explanation of no effect of those welding parameters should be that variation of those welding parameters rarely affected to the welding thermal cycle at the measured area of the intermetallic reaction layer.

3.3 Effect of welding parameters on welding width

Figure 6 and 7 show the relationship between apparent heat input and welding width with various welding speeds, and various welding currents at 2.4 mm of arc length respectively. Figure 8 shows the relationship between welding width and apparent heat input with various arc lengths. From Fig.6 and 7, it was found that the variation of welding speed and variation of welding current at particular apparent heat input was not led to vary welding width. On the contrary, the variation of arc length significantly affected to the difference of welding width as shown in Fig. 8. Using improper arc length expanded the welding width. No observation of variation of welding width in case of varying welding speed and welding current might be caused by few changing of thermal distribution in welding specimen during welding cycle. On the other hand, the altering of arc length significantly affected to thermal distribution in welding specimen during welding, which resulted in changing of welding width.

3.4 Effect of welding parameters on failure loads of joints

Figure 9 and 10 reveal the relationship between apparent heat input and failure load of joint with various welding speeds, and various arc lengths, respectively. Considering Fig.10 and 11, it was found that failure load of joint was increased with increasing apparent heat input until about 20-30 kJ of apparent heat input. Then, when apparent heat input was higher than 20-30 kJ, the failure load of joint was not altered with apparent heat input. Moreover, in fracture path observation, it was found that the joint was broken at intermetallic reaction layer zone when apparent heat input was less than 20-30 kJ. When apparent heat input was higher than 20-30 kJ, broken zone became heat affected zone (HAZ) of aluminum alloy. According above results, it could be indicated that the failure load of joint depended on the load resistance of intermetallic reaction layer and load resistance of HAZ of aluminum alloy. Furthermore, it was found that increasing welding speed and using proper arc length, failure load of joint was reached to maximum value at lower apparent heat input as shown in Fig. 10 and Fig. 11. It might be caused by high strength of intermetallic reaction layer obtained when using high welding speed and proper arc length.

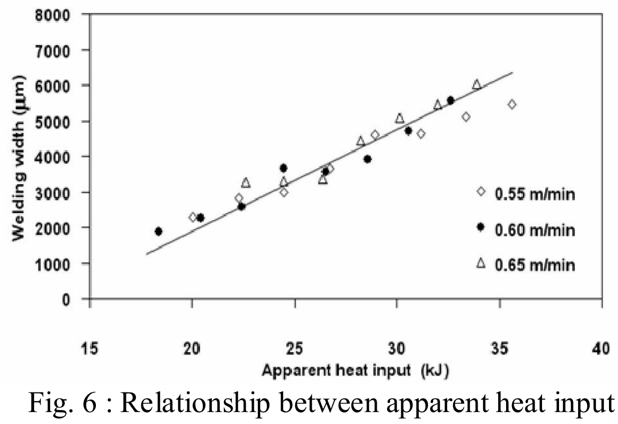

Fig. 6 : Relationship between apparent heat input and welding width with various welding speeds at 2.4 mm of arc length

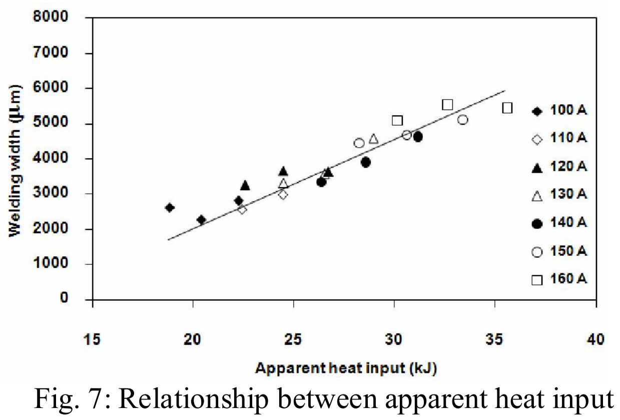

Fig. 7: Relationship between apparent heat input and welding width with various welding currents at 2.4 mm of arc length

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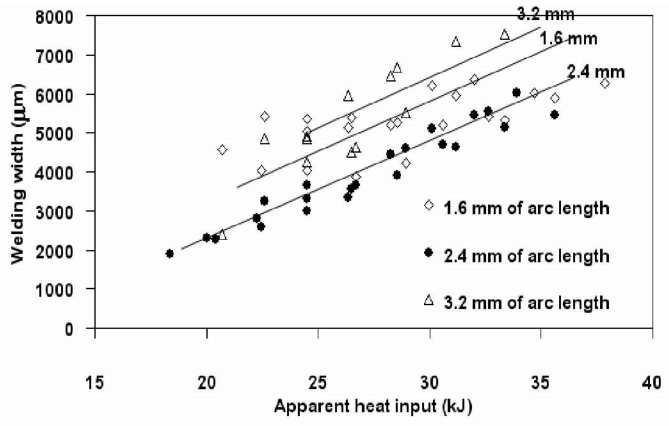

Fig. 8 : Relationship between apparent heat input and and welding width with various arc lengths

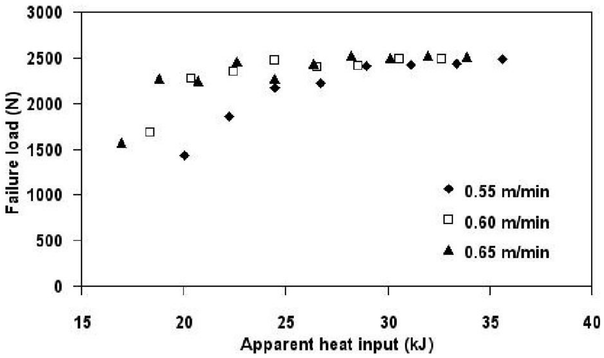

Fig. 9 : Relationship between apparent heat input and welding width with various welding speeds at 2.4 mm of arc length

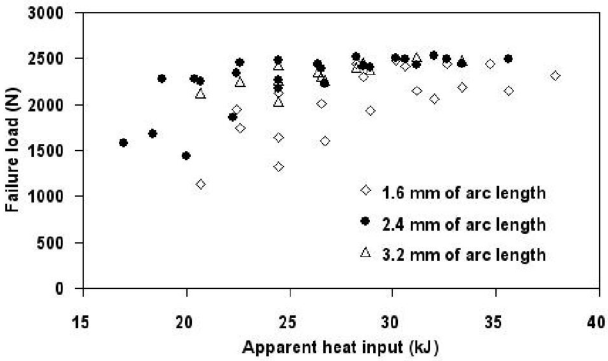

Fig. 10 : Relationship between apparent heat input and welding width with various welding speeds at 2.4 mm of arc length

4. Conclusion

Finally, it could be summarized as following.

1. At particular heat input, increasing welding speed or increasing current did not significantly affect the welding width and the thickness of intermetallic reaction layer.
2. Increasing arc length resulted in increasing weld width and in limiting welding windows, but it was not found to be a factor influencing the thickness variation of the intermetallic reaction layer.
3. The variation of welding speed and arc length has the influence on the strength of intermetallic reaction layer.

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References

[1] Borrisutthekul, R., T. Yachi, Y. Miyashita and Y. Mutoh: *Suppression of intermetallic reaction layer formation by controlling heat flow in dissimilar joining of steel and aluminum alloy*. Mater. Sci. Eng. A., 467 (2007) pp. 108-113.

[2] Y. Miyashita, I. Nakagawa, J.Q. Xu, Y. Mutoh, M. Akahori, H. Okumura, *Laser Welding of Dissimilar Metals Joint Aided by Unsteady Thermal Convection Boundary Element Method Analysis*, Quart. J. Jpn. Weld. Soc., 23-1(2005) 16-24.(in Japanese)

[3] K. J. Lee, S. Kumai, T Arai, *Interfacial Microstructure and Strength of Steel to Aluminum Alloy Lap Joints Welded by a Defocused Laser Beam*, Mater. Trans. 46 (2005) 1847-1856.

[4] M. J. Rathod, M. Kutsuna, *Joining of aluminum alloy 5052 and low-carbon steel by laser roll welding*, Weld. J., (2004) 16s-26s.

[5] F. Wagner, I. Zerner, M. Kreimeyer, T. Seefeld, G. Sepold, *Characterization and properties of dissimilar metal combinations of Fe/aluminum and Ti/aluminum sheet materials*, Proc. ICALEO 2001, (2001) 365-374.