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Observation of Arc Behaviour in TIG/MIG Hybrid Welding Process

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Abstract. In this project, the influence of TIG currents's variation on arc stability of TIG/MIG hybrid welding was studied by comparing with MIG welding process. The welding current-voltage waveform was analyzed to characterize the arc stability of the MIG arc. From the observations, the introduction of TIG arc as low as 60 A of current significantly change the MIG arc stability in TIG/MIG hybrid welding. The length of MIG arc in TIG/MIG welding increased with the introduction of the TIG arc as compared with MIG welding. The increase of arc length was due to the arc interaction between the TIG arc and MIG arc, which is affecting the wire melting rate. At the maximum TIG current, the diameter of the molten droplet decreased with the increment of droplet transfer frequency.

1. Introduction

Welding is a process whereby two or more parts of similar and dissimilar metals are joined together by applying heat and pressure to provide permanent joining. Tungsten inert gas (TIG) and metal inert gas (MIG) welding process are among the arc welding processes and they are mainly used in many industrial fields due to high productivity in welding as compared to other welding processes. Nevertheless, due to the instability of cathode spots in the base metal surface, the MIG welding process often suffers major drawback of unstable arc generation in pure shielding gas [1,2]. Thus, TIG/MIG hybrid welding process is developed to stabilize the MIG arc in pure shielding gas condition through the effect of hybridization with the TIG arc [3]. Therefore, the aim of this project is to study the stability of MIG arc with the effect of TIG arc.

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2. Experimental setup

2.1. Materials selection
Aluminium alloy (5052A) plates with dimension of 150 mm × 100 mm × 5 mm were used for bead-on-plate welding. Welding wire, A5183 with diameter of 1.2 mm was used as filler metal. 15 L/min pure argon shielding gas was used for both TIG and MIG welding in this research.

2.2. Methodology
TIG (Direct current electrode negative, DCEN) was set as trailing while, MIG (Direct current electrode positive, DCEP) was set as leading with both two torch axis angle was 60° to the steel plate, as shown in Figure 1. The horizontal distance from the tip of the tungsten electrode to the surface of the welding wire was 6 mm, and the vertical distance from the tip of the tungsten electrode to the top surface of the steel plate was 10 mm. Weld bead was formed by using MIG and TIG/MIG hybrid, respectively at the same welding travel speed of 480 mm/min. The current of MIG was fixed at 140 A. Meanwhile, the TIG current varied at 60 A, 100 A and 120 A.

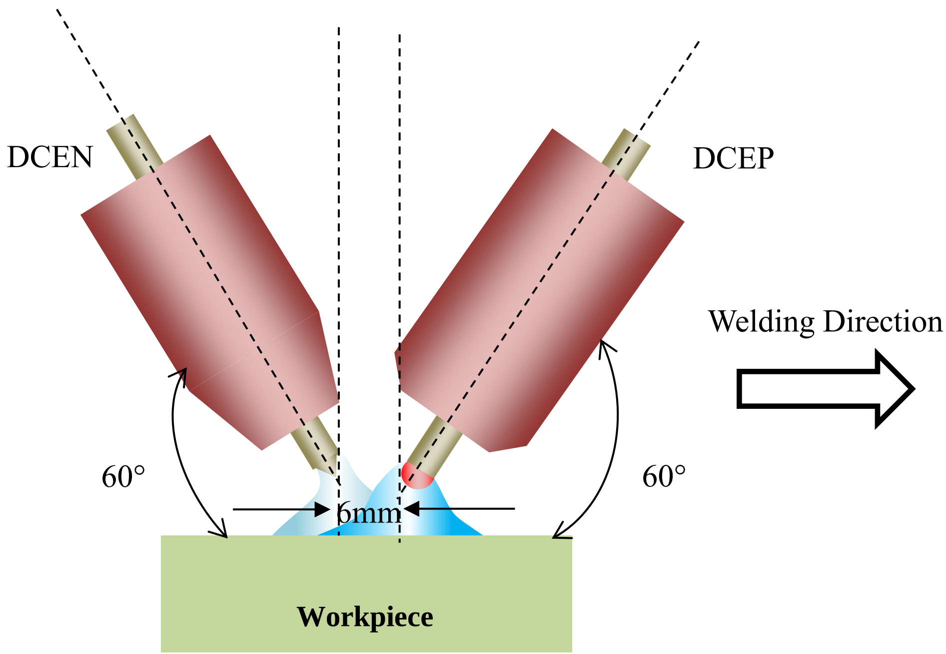

Figure 1. Schematic diagram of TIG/MIG hybrid welding torches

3. Results and Discussion

3.1. Arc Phenomenon
Figure 2 shows the arc shapes in MIG and TIG/MIG hybrid at different currents observed at perpendicular to the welding direction. From the observation, MIG arc is in bell-shaped and arc in TIG/MIG hybrid welding is broom-shaped due to the electromagnetic repulsion force generated by the TIG arc. The electromagnetic repulsion force caused by the changed in the arc heat and force distribution [4].

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The diameters (d_1 and d_2) of the arc were measured accordingly as shown in Figure 2. d_1 is a dimension of arc measured about 1 mm below the wire tip and electrode tip while, d_2 is a size of arc column about 1 mm parallel to base metal [4]. The d_1 and d_2 for MIG were 5.5 mm and 8.8 mm respectively. On the other hand, the arc diameters increased upon the introduction of TIG arc. The diameters further increased with the TIG current. The increment of arc diameter was due to the high dispersion of arc force consequence with a strong arc interaction between TIG arc and MIG arc [5]. Subsequently, this will cause lower deposition rate of molten metal, and will discussed in section 3.3

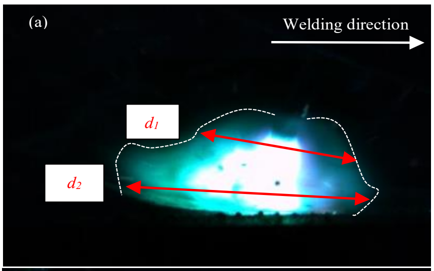
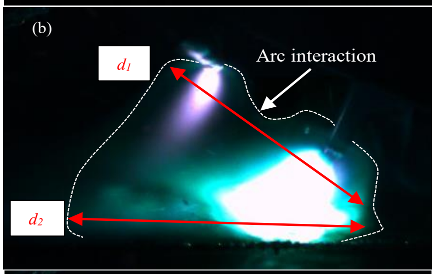
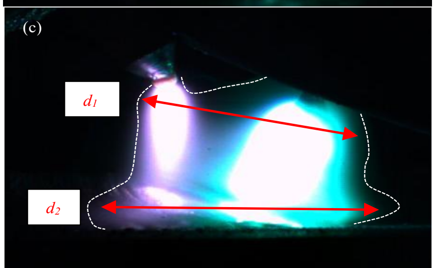
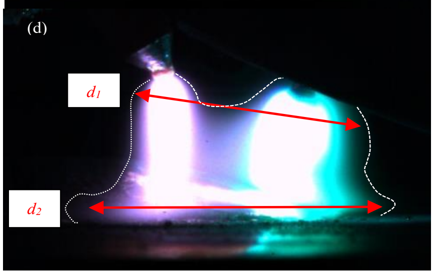
Observation	**Measurement (mm)**	
	d1	d2
	5.5	8.8
	8.5	10.2
	9.0	10.3
	10.0	13.0

Figure 2. The arc shape (a) Only MIG arc, (b) MIG140A/TIG60A hybrid welding (c) MIG140A/TIG100A hybrid welding (d) MIG140A/TIG120A hybrid welding

Figure **3** shows the observation of MIG arc length upon the introduction of the TIG arc. The arc length was measured accordingly and shown in Figure 4. According to Figure 4, arc length increased with the increasing of TIG current. This was due to the effects of electromagnetic repulsion force from the TIG and MIG arc currents. The increase of current flow would increase the electromagnetic repulsion force and affecting the arc stability as well as the droplet transfer mode. This will be explained in sections 3.2 and 3.3.

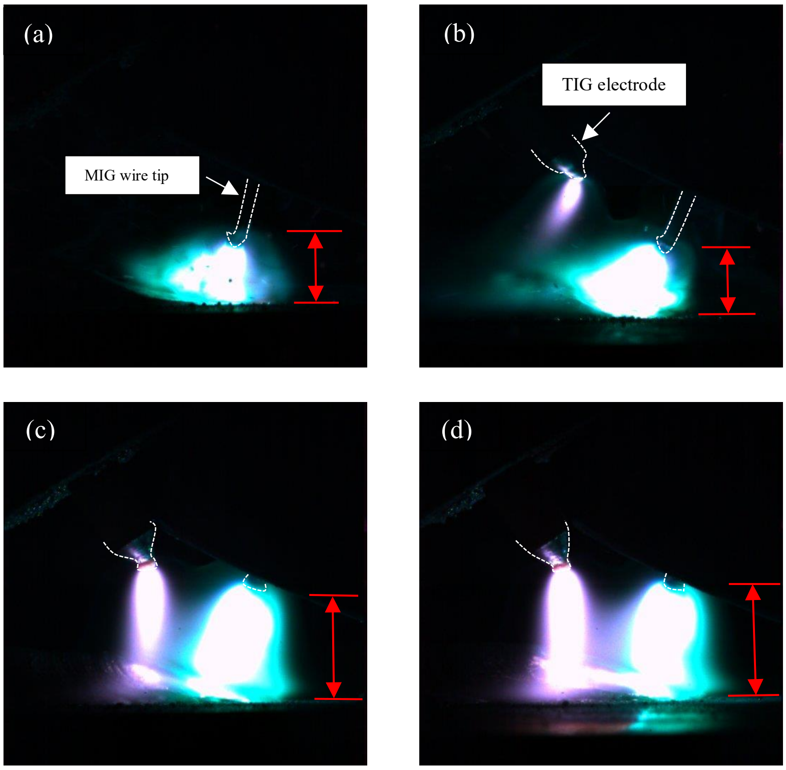


Figure 3. Influence of TIG current on MIG arc length (a) MIG welding (b) MIG140A/TIG60A hybrid welding (c) MIG140A/TIG100A hybrid welding (d) MIG140A/TIG120A hybrid welding

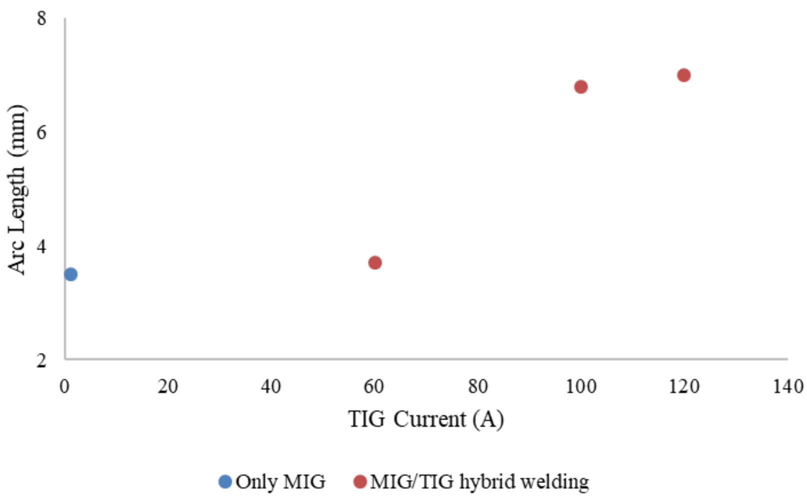


Figure 4. Influence of TIG current on arc length

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3.2. Current-voltage waveform

Figure 5 shows the comparison of a current-voltage waveform for MIG and TIG/MIG hybrid. Figure 5 (a) shows the fluctuation of current due to the disturbance movement of metal droplet transfer leading to unstable arc in the MIG. The short circuit occurred in the MIG welding process when the MIG voltage drop to nearly zero and the MIG current reach a maximum value, as a result of smaller arc length produced [6]. On the other hand, in TIG/MIG hybrid welding, the MIG current was stable as shown in Figure 5 (b) to (d). The stability of MIG current would influence the metal transfer mode.

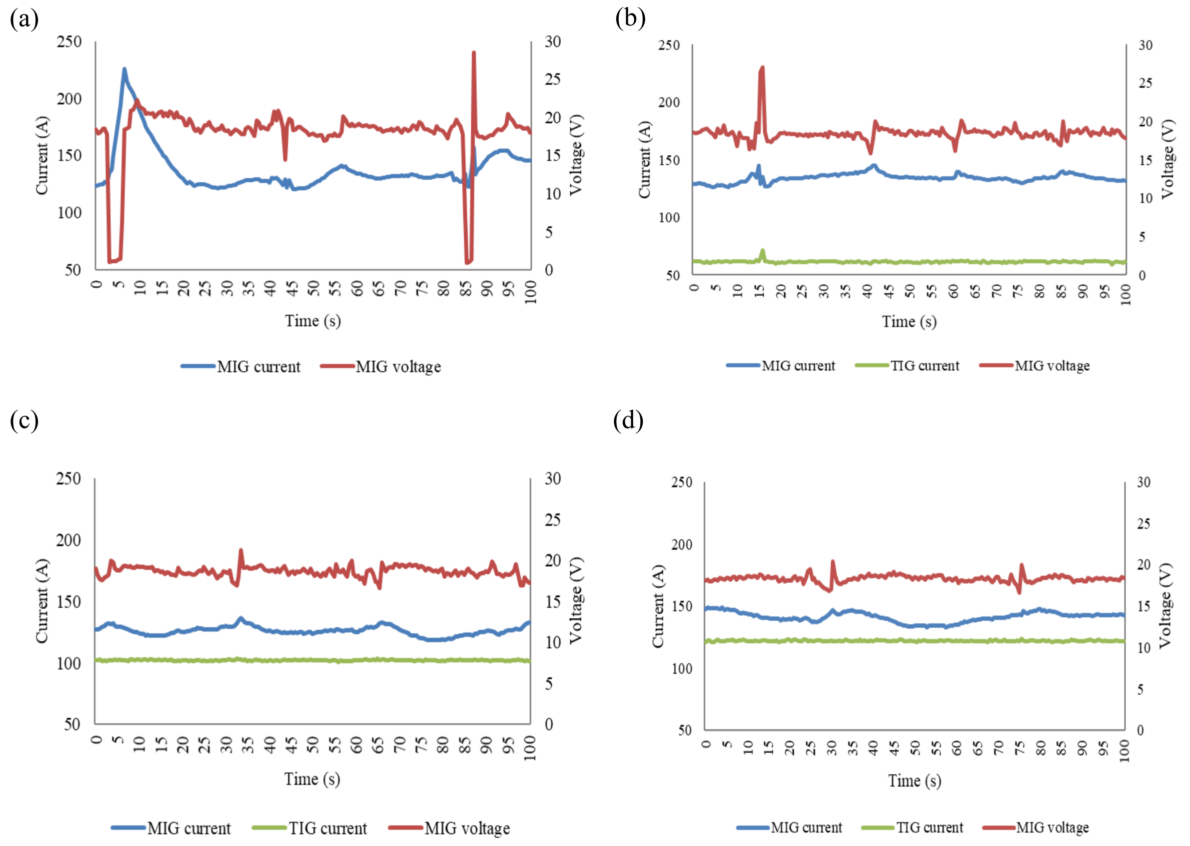

Figure 5. Comparison of a current-voltage waveform of (a) MIG welding (b) (b) MIG140A/TIG60A hybrid welding (c) MIG140A/TIG100A hybrid welding (d) MIG140A/TIG120A hybrid welding

3.3. Droplet transfer

Figure 6 shows the droplet transfer mode in MIG and TIG/MIG hybrid welding. In the only MIG welding process, the droplet was detached from the wire tip and move towards the weld pool along the wire axis under electromagnetic pinch force, plasma flow force, and gravity effect. In TIG/MIG hybrid welding, the droplet shifted away from the axis and moved forward along horizontal velocity when the electromagnetic repulsion force was applied to the weld pool surface [4].

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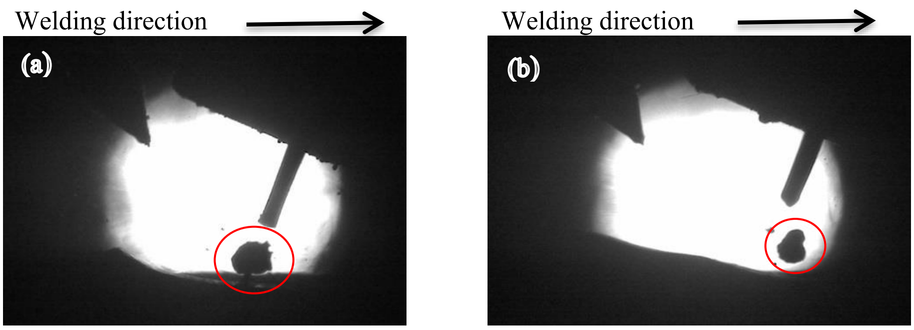

Figure 6. Droplet transfer mode in (a) only MIG welding (b) TIG/MIG hybrid welding

When the TIG arc is introduced to the MIG arc, the droplet diameter was reduced, and leading to increment of droplet transfer frequency. This is due to the electromagnetic repulsion force generated by the TIG arc has easily transferred the droplet from wire tip to weld pool. It could be anticipated that the changes of the droplet transfer mode from globular to spray transfer mode will ease the droplet transfer, and hence improving the welding quality. Furthermore, the increment of TIG current reduce the diameter of metal droplet and increase the frequency of droplet transfer as shown in Figure 7.

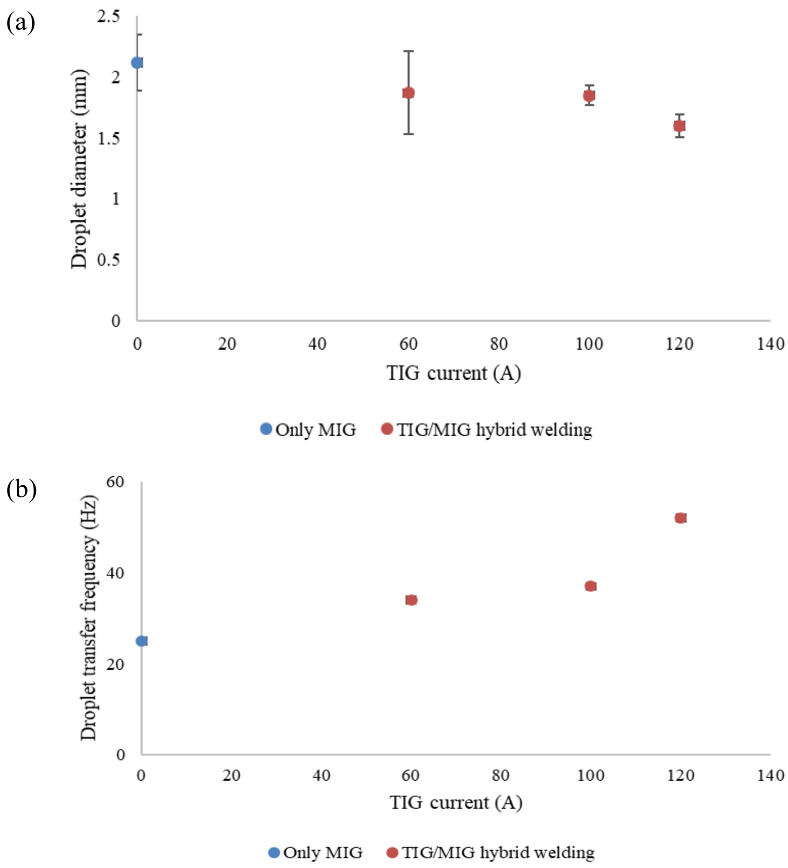

Figure 7. Influence of TIG current on droplet transfer (a) Droplet diameter (b) droplet transfer frequency

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According to Figure 7, the smallest metal droplet diameter and the highest frequency of metal droplet transfer were observed at the highest TIG current of 120A. The small diameter of the metal droplet and the highest frequency of droplet transfer was shown in 120A of TIG current. Increasing in TIG/MIG hybrid welding current produced strong interaction of arc between TIG and MIG arc and produced a high wire melting rate in MIG. Thus, it decreased the droplet diameter and increased the frequency of the droplet transfer. This can be related to Figure 2 and Figure 5 in sections 3.1 and 3.2, where small arc length produces unstable metal transfer. TIG current of 60A shown the largest error bar compared to 120A of TIG current.

4. Conclusion

The introduction of TIG current (60 A, 100A, 120A) would influence arc stability, arc behaviour, and metal droplet transfer. In TIG/MIG hybrid welding, the strong interaction of arc between TIG arc and MIG arc increases the diameter of arc and length of the MIG arc continually with the increasing of TIG current. A stable MIG arc can be achieved by hybridization effect with TIG arc. The droplet frequency was highly dependent on the droplet diameter and metal droplet transfer mode. Beyond the maximum TIG current, the droplet frequency increase with the decrease of droplet diameter due to increase in arc voltage that contributed to higher electromagnetic force on the wire neck.

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