

Effect of Pulsed TIG Welding Parameters on the Microstructure and Micro-Hardness of AA6061 Joints

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Abstract

Tungsten Inert Gas (TIG) welding process is generally used for welding of aluminum alloys. TIG process is generally preferred because it produces a very high quality weld. Distortion is the major problem in welding of thin sections. This distortion is controlled in pulsed and magnetic arc oscillation TIG process. The metallurgical advantages of pulsed TIG welding are grain refinement in fusion zone, reduced width of HAZ, less distortion, control of segregation, reduced hot sensitivity and residual stresses. It was observed that pulsed TIG welding produces finer grain structure of weld metal than conventional TIG welding (without arc pulsation). The mechanical properties (Hardness) and microstructure characteristic of weld metal depends upon the microstructure of the weld. The microstructure of the weld depends upon pulsed parameters peak current, base current, pulse frequency, pulse duration. The objective of present project is to achieve better mechanical properties. So, controlling of pulsed parameter is needed in this investigation. An increase in the pulse frequency has been found to refine the grain structure of weld metal especially when welding is done using short pulse duration. Long pulse duration lowers the pulse frequency up to which refinement of constituents in weld metal takes place. Effect of the pulse frequency on the grain structure was found to be determined by pulse duration. For a given pulse frequency, long pulse duration produced a coarser structure than short pulse duration. An increase in the peak current coarsened the grain structure.

Keywords: Tungsten Inert Gas welding; Heat affected zone; Pulsed current; Based current; Pulsed frequencies; Pulsed duration

Introduction

Aluminum and its alloys play crucial and critical role in engineering material field. The predominance of this is attributed to the excellent corrosion properties owing to the tenacious oxide layer, easy fabric ability and high specific strength coupled with best combination of toughness and formability. In the construction of pressure vessels and storage tanks, the weld ability play unique role in selection of materials from the various candidate materials. Aluminum fabrication is preferred when compared to other materials fabrication since it offers a considerable mass advantage to the extent of as high as 40% to existing materials. Also repair procedures and methodology are easily to be adopted and hence it is highly recommended for aerospace applications.

All aluminum alloys are not weldable due to the hot cracking during welding. The hot cracking is due to high solidification range (called a mushy zone) of the alloys. A few alloys are readily weldable and prominent alloys are AA 6061, AA 5053 and AA 2219. Tungsten Inert Gas (TIG) Welding provides an effective manufacturing technique that enables the welding of the parts made of alloy materials with complicated geometry that is difficult to produce by conventional welding processes. Its ability to control the process parameters to achieve the required dimensional accuracy and surface finish has placed this welding operation in prominent position in industrial applications'. Balasubramanian studied the effect of pulsed current gas tungsten arc welding parameters on microstructure of titanium alloy [1]. Titanium is one of the most important nonferrous metals. Single pass gas tungsten arc (GTA) welding of thin sections of Ti-6Al-4V was accomplished with pulsing current technique and was found to be superior to conventional continuous current process in terms of grain refinement in the fusion zone. They study the effect of pulsed current GTA welding parameters on titanium alloy weld characteristics such as grain size and hardness. It was revealed that at an optimum value of 6

Hz pulse frequency and 80 A peak current the hardness was maximum and the grain size was minimum. Pulsing current in inert gas welding was found to be beneficial in titanium welding. Rajesh Manti Dwivedi studied the microstructure of Al-Mg-Si alloy weld joints produced by pulse TIG welding, Al-Mg-Si alloys (6000 series) of are heat-treatable aluminum alloys [2]. Pulse TIG offers many advantages over conventional TIG welding as far as control of microstructure is concerned. This research investigated the effect of pulsed TIG welding parameters such as pulse duration, peak current, pulse frequency on the microstructure of heat-affected zone, and fusion line and weld metal of Al-0.5%, Mg-0.5%, Si weld joints. It was observed that a significant change in microstructure takes place in moving from the base metal to weld centerline. Dissolution of phases present along the grain boundary occurs as the fusion line is approached. Grain structure of heat-affected zone, fusion line, and weld metal appears to have tangible relationship with pulse parameters. Rajesh Manti studied the microstructure and hardness of Al-Mg-Si weldments produced by pulse GTA welding [3]. The effects of pulsed TIG welding process parameters (pulse duration, peak current, and pulse frequency) on the microstructure and micro hardness aluminum (6061) alloys was observed that pulse TIG welding produced finer grain structure of weld metal than conventional TIG welding (without arc pulsation). An increase in the pulse frequency has been found to refine the aluminum and eutectic grain structure of weld

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metal especially when welding is done using short pulse duration. Long pulse duration lowers the pulse frequency up to which refinement of constituents in weld metal takes place. Effect of the pulse frequency on the grain structure was found to be determined by pulse duration. For a given pulse frequency, long pulse duration produced a coarser structure than short pulse duration. An increase in the peak current coarsened the grain structure. Toshio Enjo and Toshio Kurodo, studied the microstructure in heated affected zone of Al-Zn-Mg alloy Microstructure of weld affected zone (HAZ) [4]. In commercial system 6063-t5 alloy. The precipitation amounts of G.P zones, β precipitates, β phase and relatively insoluble compounds respectively in the HAZ can be evaluated quantitatively by means of electrical resistivity annealing technique. The partial or all dissolution of G.P zones and β precipitates occurs in a narrow band of the HAZ where the temperature has reached above 240°C during welding. Senthil Kumar studied the effect of Pulsed Current GTA welding parameters on the fusion zone microstructure of AA 6061 aluminum alloy [5]. The preferred process for welding these aluminum alloys (Al-Mg-Si alloy) is frequently Gas Tungsten Arc (GTA) welding due to its comparatively easy applicability and lower cost. In the case of single pass GTA welding of thinner sections of this alloy, the pulsed current has been found beneficial due to its advantages over the conventional continuous current processes. The use of pulsed current parameters has been found to improve the mechanical properties of the welds compared to those of continuous current welds of this alloy due to grain refinement occurring in the fusion zone.

Present paper explain effect of parameters of gas tungsten arc welding on AA6061 on the performance of to establish the gas tungsten arc welding process on 4 mm size of AA6061 aluminum alloy work piece of the using the parameters of current, voltage, pulse on time.

Experimental Investigation

Preparation of material

An A6061 aluminum alloy plate (500 mm × 500 mm × 4 mm) was cut into 75 mm × 50 mm × 4 mm sizes. The edges of number of pieces were grinded in 60 deg and land was 1 mm to make single V butt joint configuration as shown in Figure 1. The chemical composition of the base metal AA6061 (Filler material AA4043) as shown in Table 1. The selection of the filler material is based on the mechanical properties and the resistance to cracking in the weld.

Micro hardness test

The term micro hardness test usually refers to static indentations made with loads not exceeding 1 kgf. The indenter is either the Vickers diamond pyramid or the Knoop elongated diamond pyramid. The procedure for testing is very similar to that of the standard Vickers hardness test, except that it is done on a microscopic scale with higher precision instruments. The surface being tested generally requires a metallographic finish; the smaller the load used, the higher the

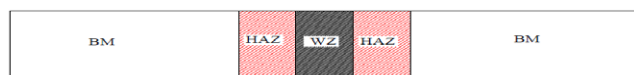


Figure 1: Specimen as per dimension.

Material	Mg	Si	Cu	Cr	Mn	Zn	Ti
AA6061	0.85	0.68	0.22	0.66	0.32	0.07	0.05
AA4043	0.05	4.8	0.17	0.05	0.24	0.05	0.05

Table 1: Chemical properties of both base metals and filler metal.

surface finish required. Precision microscopes are used to measure the indentations; these usually have a magnification of around 500 X and measure to accuracy of $\pm 0.5 \mu\text{m}$. Also with the same observer differences of $\pm 0.2 \mu\text{m}$ can usually be resolved. It should, however, be added that considerable care and experience are necessary to obtain this accuracy.

Optical metallography

For the optical microscopy the samples were cut in a direction perpendicular to the welding direction. These samples were then grinded successively on SiC papers of grit 220 to 600. After which they were polished with emery papers of grade 1/4, 2/4, 3/4, 4/4 respectively. Then samples were polished on a fine cloth using a 1 μm diamond paste to obtain a mirror finish. The samples were then etched using a solution of 5 ml HCl+95 ml H₂O (distilled water). These were then used for optical microscopy of magnification 100 X with inbuilt camera. Test method IS: 7739 part 111-1975 (RA2003).

Results and Discussion

Micro hardness test

The weldments are prepaid with pulse and without pulse in different heat inputs as shown in Figures 2 and 3. Micro hardness study on different zones of specimens corresponding to each welding condition was analyzed to ensure repeatability. The micro hardness (VHN) of weld metal was tested at constant load of 100 g. The micro hardness of different weldments are given in Table 2. The heat input valve is calculated based on the equation: Heat input=[(V × A × 60)/(S × 1000)] × efficiency (For MIG, efficiency=0.9)=[(26 × 160 × 60)/(3.295 × 1000)] × 0.9=1.136 (kJ/mm).

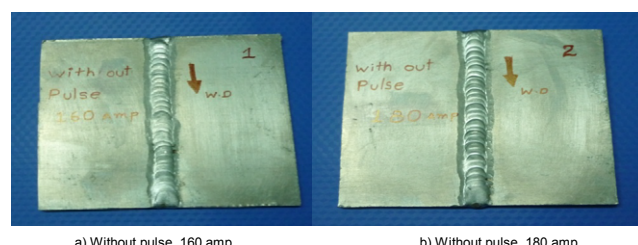


Figure 2: Welding joint produced without pulse.

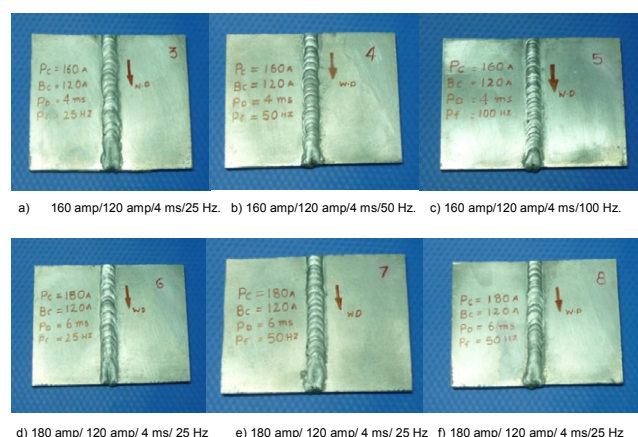
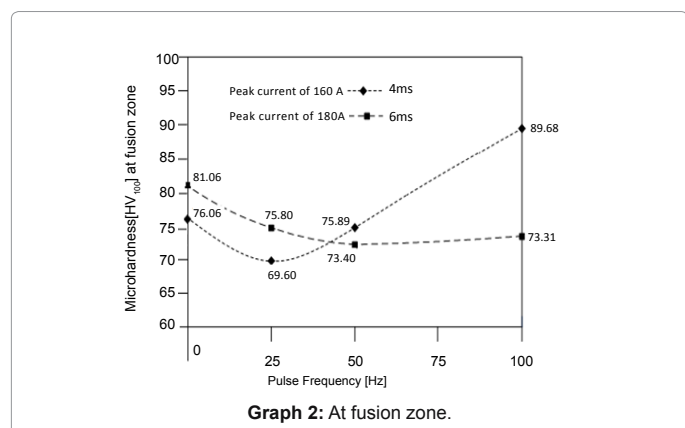
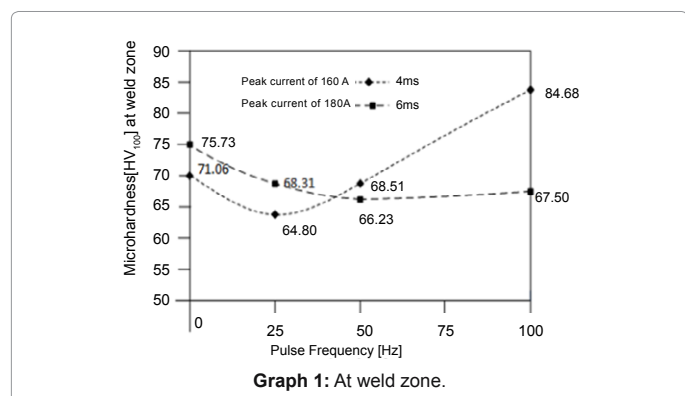


Figure 3: Welding joint produced with pulse at different inputs.

No	Peak Current (A)	Base Current (A)	Pulse frequency (Hz)	Pulse duration (ms)	Heat Input	Microhardness (HV)		
						Weld Zone	Fusion Zone	HAZ
1	160	0	0	0	53.787	71.06	76.06	87.38
2	180	0	0	0	60.511	75.73	81.06	82.06
3	160	120	25	4	54.673	64.8	69.06	75.68
4	160	120	50	4	56.250	68.5	75.89	80.23
5	160	120	100	4	55.987	84.68	89.68	95.67
6	180	120	25	6	59.675	68.31	75.80	81.36
7	180	120	50	6	60.564	66.23	75.89	78.48
8	180	120	100	6	60.255	67.5	73.31	79.46

Table 2: Microhardness at different zones results.



Micro hardness at each zone: Results showed that the effect of pulse frequency on the micro hardness is determined by pulse duration and peak current. The micro hardness (HV100) of the weld metal produced using 160 A peak current for 4 ms pulse duration showed that increase in pulse frequency from 0 to 25 Hz decreases the micro hardness up to 64.80 HV followed by continuous increase in the hardness 84.68 HV at 100 Hz pulse frequency.

Graphs on influence of pulse frequency on peak current of 160 A and 180 A: At each zone

The weld metal produced using 180 A for 6 ms pulse duration showed in the Graphs 1-3 at each zone that increase in pulse frequency from 0 to 25 Hz decreased the hardness 68.31 HV followed continuous decrease in the hardness 67.50 H.V up to 100 Hz pulse frequency. Maximum hardness obtained at 50 Hz pulse frequency. Longer pulse duration (6 ms) produced lower micro hardness of the weld metal than

that produced by shorter pulse duration (4 ms) especially at higher pulse frequencies (50 and 100 Hz). The micro hardness (HV100) at the fusion zone produced using 160 A peak current for 4 ms pulse duration showed that increase in pulse frequency from 0 to 25 Hz decreases the micro hardness up to 69.60 HV followed by continuous increase in the up to 89.68 HV at 100 Hz pulse frequency. The weld metal produced using 180 A for 6 ms pulse duration showed that increase in pulse frequency from 0 to 25 Hz decreased the hardness 75.80 HV, followed continuous decrease in the hardness 73.31 H.V up to 100 Hz pulse frequency.

Microstructures study (Pulse frequency and microstructure study)

The grain structure results showed that the pulse parameters such as pulse frequency, pulse duration and peak current affect the grain structure of weld metal appreciably. Influence of the pulse frequency on the microstructure is shown in Figures 4a-4d. It is observed that increasing the pulse frequency from 0 to 100 Hz lowers average grain size.

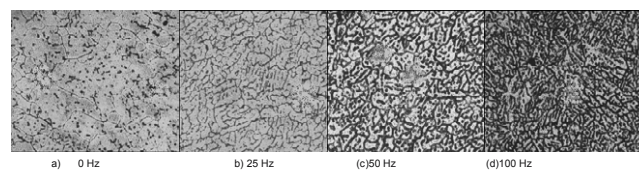
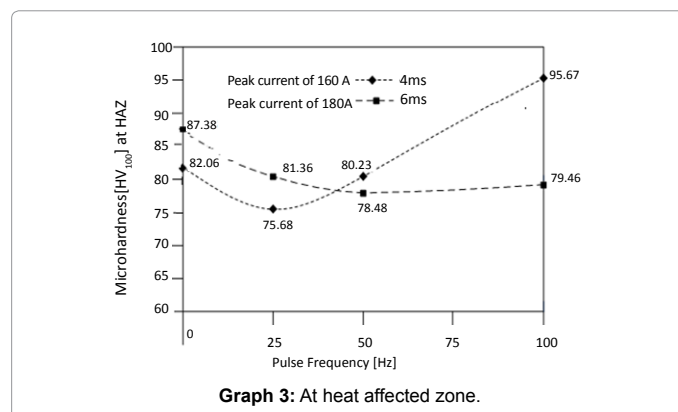


Figure 4: Micro structures with different frequencies.

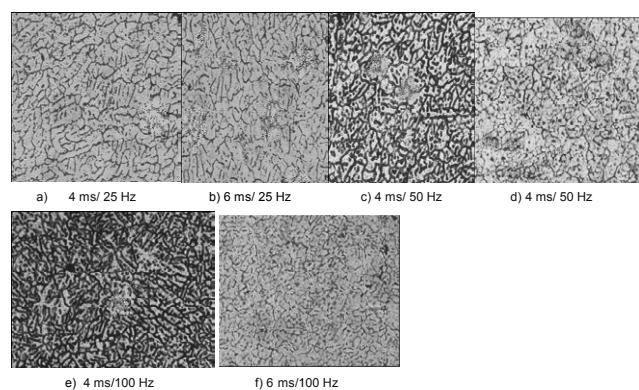


Figure 5: Micro structures from two pulse duration with different frequencies.

Influence of pulse duration study

Influence of pulse duration study can be explained by Figures 5a-5f.

Conclusions

Weldments were produced using two pulse durations, i.e. 4 ms and 6 ms, at four pulse frequencies (0, 25, 50 and 100 Hz). The influence of the pulse duration on microstructure is shown in Figures 5a-5f. It was observed that for a given pulse frequency short pulse duration (4 ms) produced finer grain than long pulse duration (6 ms). Aluminum grains produced using 6 ms pulse duration was found coarser than conventional TIG welding (without pulsing) irrespective of pulse frequency. The refinement of grain structure with an increase in the pulse frequency from 25 to 100 Hz (4 ms pulse duration) may be due to greater turbulence in the weld pool which would encourage the fracture of growing dendrites to provide a large number of nuclei. Increased net heat input at 6 ms pulse duration lowers the pulse frequency up to which grain refinement takes place. High net heat input above 50 Hz pulse frequency (6 ms pulse duration) can cause the grain growth due to reduced rate of solidification and increased solidification time. The weldments were also made using two levels of peak currents, 160 A and 180 A, and four pulse frequencies (0, 25, 50 and 100 Hz). It can be observed that for a given pulse frequency low peak current produces

finer aluminum grains than high peak current. Because pulsing of the current between the base and peak current might cause under cooling of the liquid metal in the weld pool because net heat input to the weld pool is suddenly reduced during the base current part of pulse TIG welding. This under cooling may cause surface nucleation by producing many nucleants at the surface. These nucleants may later get distributed into the molten weld pool. A large number of nucleants produced by any means would result in grain refinement in the weld metal.

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