

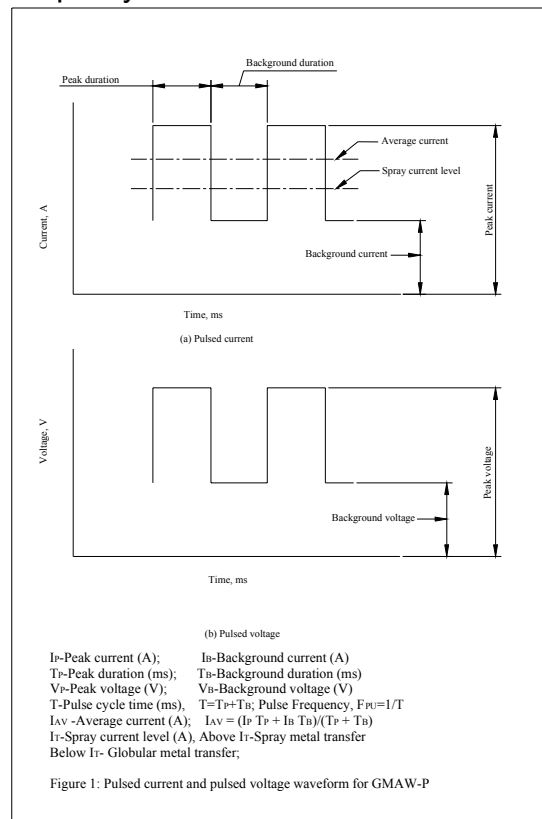
D. The Experimental Approach on the Process-Integrated Quality Assurance in Pulsed GMA Welding of Al-Mg Alloys

by Dr. S. Rajasekaran, M.E., Ph.D (IIT- Bombay), Director, Mahendra Engineering College, Mahendhirapuri, Namakkal 637 503, Tamilnadu, India.

Introduction

The automotive industry is interested to furthering the use of Al-Mg alloys in the production of new breed lightweight cars. The pulsed current gas metal arc welding (GMAW-P) is widely used to weld these alloys. Selecting the parameters of GMAW-P is very important as melting phenomena of the filler metal, arc stability and quality of the weld mainly depends upon it. Selecting the most suitable GMAW-P parameter is very complex due to interdependence of parameters. Therefore, in this research paper, an optimum GMAW-P parameter was selected on the basis of process-integrated quality assurance. Because, this basis enables online monitoring of welding voltage as well as the reproduction of welding data and complete documentation of all parameters and welding machine adjustments.

In GMAW-P, the current fluctuates between a high peak current for the pulses and a low background current in a regular cycle (Fig. 1). The molten metal is detached either as a single droplet or multiple droplets depending upon the pulse parameters, namely peak current (I_P), peak duration (T_P), background current (I_B), and background duration (T_B). If it is a single droplet, this detachment may occur either in peak duration or background duration, and if it is multiple droplet detachment, the detachment may occur in peak duration. This difference in the timing of droplet detachment affects the arc stability and the overall quality of the weld.

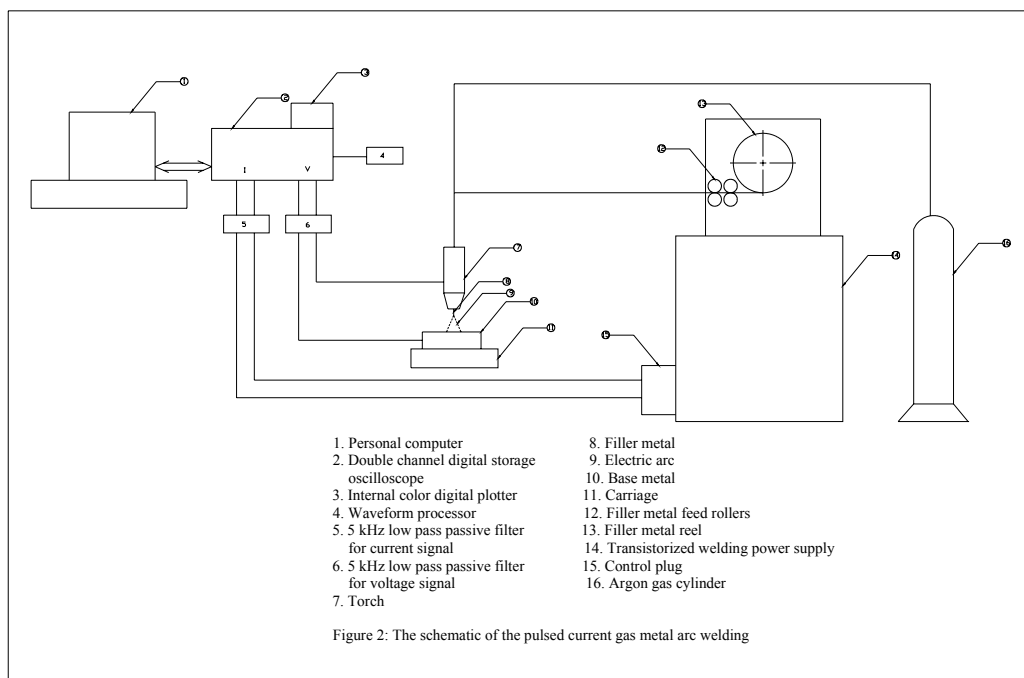


There are also shortcomings in the conventional GMAW-P process. First, setting of GMAW-P variables can be very complicated. Secondly, it has a poor self-adjust ability in response to accidental arc length disturbance. Studies on the arc characteristics are very important to understand the stability of arc under various pulsing conditions. Therefore, studies are carried out by focusing efforts on solving these problems.

Procedure

The welding was carried out using a transistorized pulsed GMA welding power supply and solid filler metal ER 5356 Al-Mg alloy having a diameter of 1.2 mm (0.047 in.) and with the compatible AA 5083 Al-Mg alloy of 6.0 mm (0.236 in.) thick base metal. Argon gas having a commercial purity of 99.97% and a flow rate of $3.333 \times 10^{-4} \text{ m}^3/\text{s}$ was used throughout the welding as a shielding gas.

A transistorized welding power supply was used for carrying out GMAW-P operations (Fig.2) in a pulsed current mode, operating with constant voltage output characteristics. In the pulsed current mode, peak voltage, background voltage, peak duration, and cycle time can be vary over the ranges 10 to 40V, 10 to 30V, 1 to 15ms and 3.3 to 50 ms, respectively. Direct setting of levels at peak and background current is not possible with the welding power supply used in the present study. Hence, levels of peak and background voltage were adjusted by trial and error to obtain the desired peak and background current levels, which were measured using high speed, double-channel, and digital storage oscilloscope. The peak duration, wire feed speed, and cycle time could be independently adjusted using the welding power supply control.



The waveforms, which were captured by a high speed, double channel, digital storage oscilloscope (Gould 4072) were not clear. Moreover, carrying out any measurements on the waveform was difficult because of the poor appearance of the waveforms. Therefore the problem of high frequency noise and process noise in the

signals of the voltage and current was discussed with the manufacturer and eliminated from the signals using two 5 kHz low pass passive filters as shown in Fig. 2. Totally, two filters were designed and fabricated. The first one was used for the pulsed voltage signal and the second one for the pulsed current signal. These filters permit frequencies below 5 kHz to pass but reject all other frequencies, which are above 5 kHz. Since the expected molten droplet frequency is well within 5 kHz, the droplet detachment phenomena could be clearly studied from the voltage spikes on the waveforms of pulsed voltage.

The pulsed current was sensed from the power supply and the pulsed voltage was sensed between the base metal and the contact tip. Sufficient time was allowed during welding to reach a stable welding condition. For this, the delay time was set in the oscilloscope and then instantaneous current and voltage were monitored and recorded simultaneously with a high speed, double channel, digital storage oscilloscope (Gould 4072) through 5 kHz low-pass passive filters (Fig. 2).

Droplet detachment was observed from the voltage spikes on the waveform of the pulsed voltage. There were variations in the peak voltage values along the peak duration apart from those owing to the intentional pulsing. The reason for these variations is that when the droplet was transferred, the instantaneous arc voltage momentarily increased and formed voltage spikes on the peak voltage levels along the peak duration. Droplet detachment time and the number of droplet detachments were obtained from the pulsed voltage traces.

Stored waveforms of pulsed current and voltage were transferred from the oscilloscope to a personal computer and saved for later analysis. The personal computer was equipped with the General purpose Instrumentation Bus (GB-IB) for current and voltage data acquisition. Totally 1000 data samples were saved during each welding experiments. Analysis of the fluctuations of these values as a function of various pulsing parameters was useful to understand arc's behavior and this could be correlated to the various types of molten metal droplet detachments.

The flat position bead-on-plate welds were prepared under mechanized conditions at a fixed welding speed of 10 mm/s and fixed wire speed of 10 mm/s. The welding torch was positioned normal to the base metal surface. Filler metal was connected to the direct-current-electrode-positive (DCEP) polarity. Prior to welding, the oxide film was removed from the base metal by mechanical means. The welding torch was mounted on four-wheeled variable speed tractor (Esab A2 Mini trac). It was moved above the base metal and welding was carried out (down hand type) in the rolling direction of base metal. The torch-to-work-angle and contact tip-to-work distance were maintained at 90° and 15 mm, respectively. The most suitable parameters of the pulsed current and the type of droplet detachment to obtain a good quality weld were selected on the basis of uniformity of average current.

First, the effects of GMAW-P parameters on the various types of droplet detachments were studied. Secondly, the average voltage per pulse cycle time was measured from the each pulse voltage waveform and the values of mean, standard deviation (s), and coefficient of variation (C.V) were calculated. The optimum GMAW-P was selected by choosing the pulse parameter which resulted in the least standard deviation and C.V of average voltage per pulse cycle time, to produce cost-effective, spatter free, high quality welds.

Results and Discussion

The lowest standard deviation and the lowest C.V for the average voltage were observed for the welds which was made with one droplet detachment during peak duration. The smaller the standard deviation and the smaller the C.V, the more uniform the average current is. That means this type of droplet detachment provides a droplet from the filler metal tip regularly during peak duration in order to produce spatter free, high quality, and stable weld. Hence, one droplet detachment during peak duration was considered to be the best for providing a more uniform average voltage than the other types of droplet detachments.

Therefore, only the GMAW-P combinations which provides one droplet detachment during peak duration, are suitable for carrying out good quality weld. The above parameter combination can be programmed to the computer so that whenever operator wants to use the particular wire feed rate, automatically this particular pulsed waveform is selected, and the operator gets good quality weld. Thus process-integrated quality assurance of the weld can be possible on the basis of more uniform average voltage. This technique facilitates research into process-integrated quality assurance and to improve the design of GMAW-P equipment to ensure that preferred welding parameters are used and to research the cause of variable performance of GMAW-P equipment in actual practice.

The study can also be extended to monitor the manual skill of welding machine operators during their training or actual work. Importantly during underwater welding, the instructor cannot find out the weld quality because of poor visibility of the prevailing or existing condition. Furthermore, the σ and C.V of the weld, which was welded with one droplet detachment during background duration, was found to be the second best in terms of the uniform average voltage. This above experimental work can be suitably extended to the other wire feed rates in order to achieve stable weld.

Conclusions

Only the one droplet detachment during peak duration was desirable because the standard deviation and C.V of average voltage were found to be the lowest, among from the four types of droplet detachments. This study can be very much useful for fabricators to derive the fullest benefits from GMAW-P in high quality or automatic or robotic welding.

This can be very helpful for monitoring and improving the GMAW-P process and for optimizing the GMAW-P process, filler metal, welding equipment, and power sources.

Statistical analysis of fluctuations in average voltage per pulse cycle time using a P.C can provide a quantitative assessment of welding arc stability.