Gas Tungsten Arc Welding In-process Monitoring Techniques for Electronic and Medical Device Applications

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Introduction

Resistance welding and laser welding are the dominant joining processes used in small-scale manufacturing where material thicknesses are generally less than 0.5 mm. Electronic applications such as lamps and sensors commonly use overlap joints, as do medical devices including endoscopic surgical devices and ablation tools.

In-process Monitoring Considerations

While multiple joining processes are available for these applications, manufacturers must also be able to effectively judge weld quality. In-process monitoring systems are readily available for resistance welding, employing commercially available off-the-shelf equipment for collection of weld current, voltage, electrode force, and electrode displacement. Even the simplest resistance welding monitors have analysis capabilities which allow the user to define limits for in- and out-of-specification conditions and will alert the operator when routine maintenance tasks such as re-dressing or changing of the welding electrodes are required.

While laser welding is effectively used to make high-quality welds, it presents a number of unique issues. Among these are difficulty welding highly reflective metals such as copper, significantly higher equipment costs, and the need for expensive light-safe guarding.

While systems are available to check laser power before and after the weld, an industry-accepted in-process monitor does not exist. As a result, EWI has been investigating the use of gas tungsten arc welding (GTAW) as an alternative process for these applications.

Gas Tungsten Arc Welding for Small-scale Manufacturing

Small-scale GTAW may present a solution to laser welding's cost, safety, and in-process monitoring challenges. As part of an internally funded project, EWI selected two common micro-GTAW applications to evaluate in-process weld quality measurement methods, focusing on edge welds on copper plates, and spot welds on stainless-steel foils.

To facilitate this investigation, EWI obtained Amada-Miyachi's MAWA-300A Precision Micro-GTAW System and a transducer from Computer Weld Technology to allow measurement of arc voltage. For each application, EWI monitored weld current and voltage while systematically varying process settings to affect weld quality. The objective of these trials was to determine if indications could be seen in the waveforms collected, and whether these indications could then be used to predict weld quality in production processes.

Approach

A 10X magnification Toroidal coil pickup was used in conjunction with the Amada-Miyachi ADAM resistance weld monitoring system to capture weld current, and arc voltage was measured at the workpiece and the tungsten electrode. Since the monitoring system was designed for levels below 10 volts, an attenuating transducer was required to compensate for the 360 volts used to establish the welding arc. Baseline process settings were developed for each application to repeatedly produce welds of suitable quality. Once baseline current and voltage waveforms were captured, electrode stand-off and alignment were adjusted to produce welds of unsuitable quality.

Edge Weld Trial Results

Initial trials focused on copper-plate edge welds. Weld time and current were not varied, since these parameters are part of the closed-loop control and are programmed into the power supply, making them unlikely to vary in production. Regardless the of weld conditions, current was found to be stable and repeatable, illustrating the effectiveness of closed-loop DC control for these welds (Figure 1).

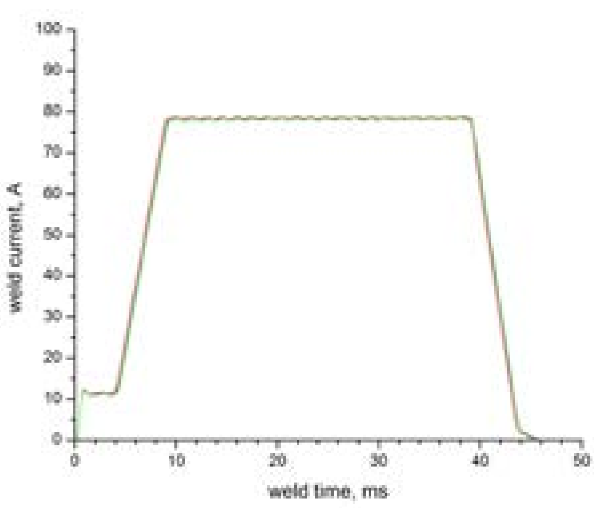

Figure 1: Current traces for three edge welds on copper plate under varying weld conditions.

Variations made to electrode stand-off and alignment were clearly visible in the recorded voltage waveforms. Since voltage can be directly correlated to arc length, these measurements are an effective method of checking for material-melt-back and damage to the tungsten electrode. The red and white traces in Figure 2 show the voltage of normal welds, while the higher voltage reading of the green trace indicates melt back resulting from intentionally welding near the corner of the specimen.

These results indicate that weld voltage monitoring can be used to nondestructively evaluate weld quality for this small-scale application. With modern weld monitoring systems, upper and lower limits can be set and output signals can be programmed to quickly flag poor weld quality or equipment issues.

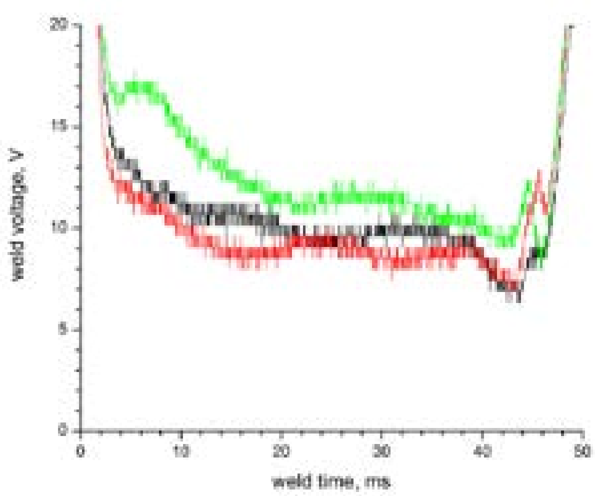

Figure 2: Voltage waveforms from three separate copper edge welds.

Spot Weld Trial Results

EWI then produced GTAW spot welds between two layers of 75-micron stainless steel sheets;

a typical weld joint in battery and medical device manufacturing. Once suitable baseline weld settings were developed, the torch stand-off was increased to produce a "no-weld" condition. This increased stand-off was easily identified in the captured voltage waveform.

Conclusions

These trials indicate that when using a closed-loop DC welder, monitoring current alone is not an effective method of monitoring weld quality. Typical weld issues which lead to a decrease in weld quality, such as a "no-weld" or a burn-back, were clearly observed in the weld voltage traces providing an effective method of real-time weld quality monitoring.

__Tim Frech__ is a Senior Engineer with EWI, having been with the company since 1990. During his tenure he has been responsible for numerous contract R&D projects for various clients in the electronics, automotive, and medical device industries. His expertise is in the areas of microwelding, ultrasonic metal welding, ultrasonic soldering, wire bonding, and resistance welding. He is also experienced in plastics joining, laser welding, and helium leak detection. He has directed projects and conducted hands-on work in welding of electronic modules, electric vehicle batteries, and medical devices.