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The Weld Nugget™

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Parallel Gap Resistance Welding

Resistance welding is a process that uses direct contact between the electrodes and parts for application of force and current. In vast majority of applications, the two electrodes approach the parts from opposite sides to pinch the stack at the intended weld location; some aspects of the resistance welding have already been covered in previous newsletters (Summer 2015, Fall 2015, Winter 2016, Summer 2020, Spring 2021). Parallel gap resistance welding is a unique variant where both electrodes are on the same side and contact only the upper part of the stack to be welded. The electrodes typically are positioned next to each other with a fixed gap, and hence the name parallel gap resistance welding, as seen in Figure 1. In this newsletter, we will review the nuances and challenges in setting a robust process for this configuration.

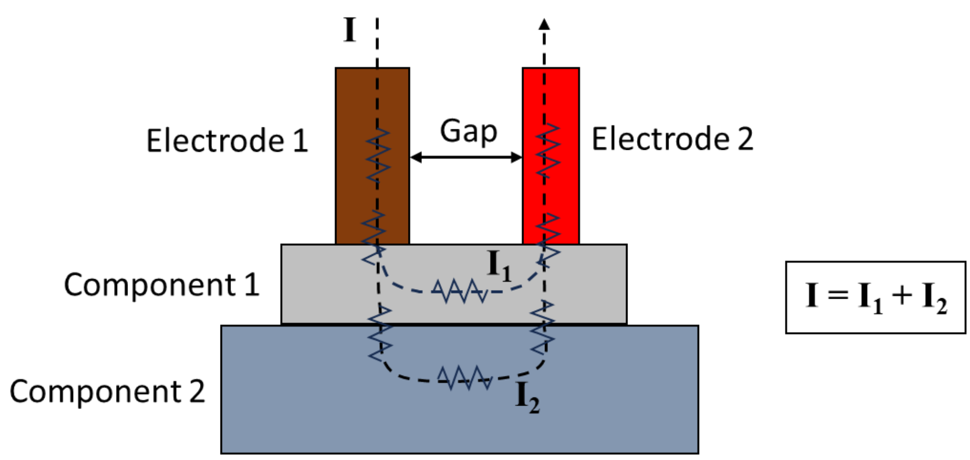

Figure 1. Schematic shows layout of parallel gap resistance welding with two parallel electrodes. The two electrodes can be of different materials, cross-section, have different welding force, and polarity (for DC welding). Materials being welded can also be different in terms of thickness, material, and overall dimension. Squiggly lines denote different resistances to current flow including bulk and contact resistance.

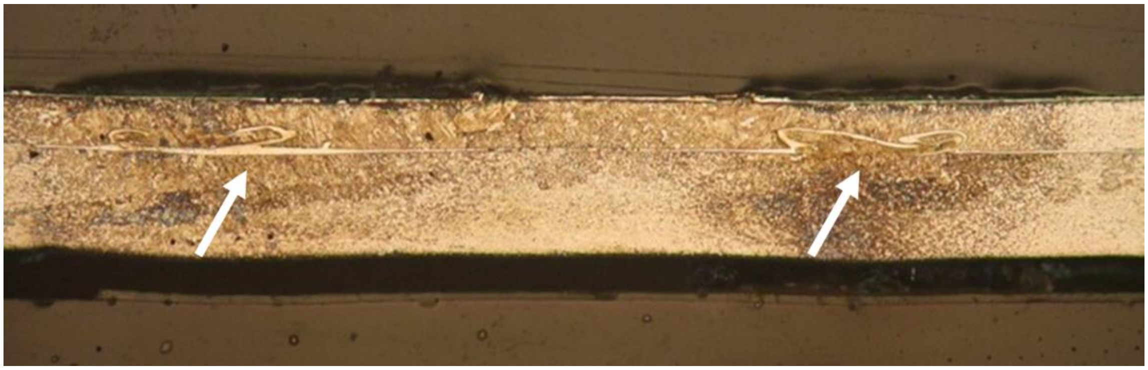

Figure 2. Weld section shows two weld spots made in a single weld pulse. Weld locations are outlined with white arrows. Depending on design and welding parameters, the weld can be fusion, braze, or a solid-state bond.

The most unique aspect of parallel gap welding is the fact that the welding current has opportunity for two current paths; distribution of current between the two depends on conventional welding parameters energy, and time, but now we have additional parameters of independent welding force, gap between electrodes, ratio of component thickness, and component resistivities. Effect of these additional parameters is as follows:

Welding Force

As with any other resistance welding process, an increase in welding force reduces resistance to flow of current from electrodes to the part. However, since the two electrodes can be activated separately (in contrast to regular resistance welding), the two electrodes can have different welding force; a feature that can be used to compensate for polarity effect when direct current welding is used. Welding force affects resistance across the electrode/component interface, and also affects resistance at the weld interface. Higher force reduces interface resistances and encourages greater amount of I2 current.

Electrode Gap and Part Resistance

Gap between the electrodes is another factor that can change the balance between current flow I1 and I2. As the gap increases, I2 component can increase especially if the upper component is thin and resistive compared to the lower component.

With proper selection of force, gap, component thickness and materials, the welding process can be setup such that I2 is large enough to generate sufficient heat at the interface between two parts to produce a weld. If the gap is wide enough, two separate weld nuggets may form, but if the gap is narrow, the two welds may merge to form a single nugget. If the parts are plated, welding conditions may result in formation of a braze joint or a mixed braze/fusion joint, as seen in Figure 2.

While parallel gap welding appears to offer many opportunities, process optimization does have many challenges, as follows:

1. Welding force is often limited by secondary damage to the device which is being welded including batteries and solar cells.
2. Electrode gap is also usually limited by part design, access, and ability of automation to achieve robust positioning of the electrodes.
3. Since all weld monitoring is done external to the weld (voltage is measured at the electrode holders, and current is measured in the secondary loop), it is not possible to know with certainty the actual values of I1 and I2. Hence weld monitoring in parallel gap welding can only be used for an approximate assessment of quality.
4. Since this a contact process, optimal material selection may also be limited by choices available for electrode materials. While certain electrode materials may be better suited based on electrode resistance, they may not be suitable based on electrode sticking.
5. Typically, the lower layer is thicker and provides an easier path to current flow, but that may not be the case in specific applications.

Like all resistance welding processes, this one is deceptively simple at first glance till the engineer starts digging through the nuances and realizes it is much more complicated. A healthy sense of respect for the process will keep engineers on their toes and keep them for eating a humble pie.