Resistance Projection Welding Provides a Low Cost Method to Manufacture Medical Device Batteries and Capacitors

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Over the last decade there has been a significant increase in the quantity of medical devices employing leading edge battery and capacitor technologies to provide a safe and reliable energy source. Although laser welding is often used during manufacture of these components, a maturing device market and rising health insurance premiums are putting pressure on manufacturers to lower their component costs.

The use of small scale resistance projection welding may provide a cost effective alternative to manufacture battery and capacitor cover assemblies. This article will review the various resistance projection weld methods and the benefits they provide. The projection weld technique will then be applied to joining a titanium ball to a battery cover's fill port. Finally, a preliminary weld schedule will be developed and analyzed to understand the critical process parameters.

Resistance Projection Welding

Resistance projection welding is an extension to traditional resistance spot welding. The difference is the parts being joined have features that concentrate the weld energy and pressure to specific interfacial locations. In general, there are three basic projection weld joint configurations:

1. Formed or machined spherical or elongated bosses
2. Mismatched geometrical surfaces
3. Annular features.

Each configuration can be applied to overcome resistance spot weld problems, material issues or to increase joint consistency and reliability. Resistance projection welding provides a high current density at the part interface. The result is fast and focused heating, and a robust weld joint that is tolerant to variations in feature size, surface finish and material properties.

Resistance Projection Weld Advantages

Designing parts with projections offers many manufacturing advantages and can often make parts that are difficult to resistance weld much more consistent.

One challenge in resistance welding is joining parts that have an unequal thermal mass because one part is considerably thicker than the other. Using a projection feature helps focus the heat generated at the interfacial surfaces and minimizes bulk heating of the parts themselves. Bulk heating is the unwanted heating of the part material away from the weld joint and causes a significant heat imbalance when one part is much larger than the other.

A second challenge is resistance welding parts that have low electrical resistivity. Resistance welding relies on Joule heating to heat the material to either its melting temperature for fusion welding or approximately 75 percent of its melting temperature for solid-state welding. Materials that have low electrical resistance like copper, aluminum or silver alloys can be reliably projection welded because the projection greatly increases the current density and confines the current flow to a defined location. Since material resistance increases with temperature, the localized heat increases the Joule heating efficiency for conductive materials.

Besides addressing common resistance weld material challenges, projection welding allows multiple weld nuggets to form simultaneously. One weld cycle, typically a fraction of second, results in a completed weld. Short cycle times and relatively inexpensive equipment are important manufacturing advantages compared to other joining technologies like laser welding.

Low tolerance part features combined with the ease of assembling parts that naturally self-center are other important cost reduction drivers associated with projection welding.

Battery and Capacitor Weld Covers

Medical device batteries and capacitors that rely on wet electrochemical cells must be hermetically sealed. The battery and/or capacitor are key electrical components for defibrillators, pacemakers, spinal cord stimulators and pumps to treat serious medical conditions. These devices are usually surgically implanted in the patient and therefore must not leak electrolyte onto the electrical circuit. A reliable hermetic seal is critical in preventing this failure mechanism.

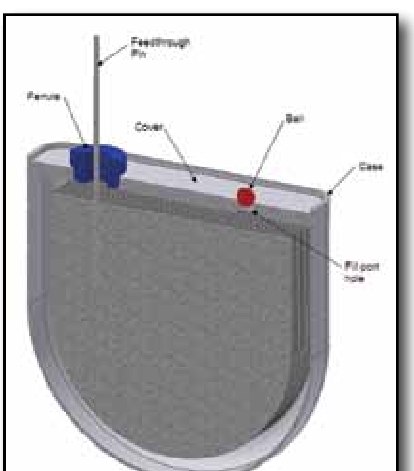

Figure 1. Generic medical device battery cross-section showing projection weld candidates: Ferrule (blue) and Ball (red)

For example, a generic 'D' shaped battery is shown in Figure 1. Medical batteries and capacitors are usually constructed from titanium due to its low weight and corrosion resistance. This article focuses on using resistance projection welds to secure the ferrule and fill port ball to the battery cover. These two joints have traditionally been made using Nd-Yag laser welds, but this can be a time consuming process that requires tightly toleranced components and expensive equipment when compared to resistance welding.

The ferrule to cover joint and ball to fill port hole joint both rely on mismatched geometric surface projections to form a hermetic joint. In either situation, a single weld cycle, consisting of two pulses of energy, form the joint. The entire weld is completed in less than 250 ms, providing extremely short cycle times.

Ball to Fill Port Hole Weld

To learn more about small scale projection welding and its process parameters, the ball to fill port hole joint was investigated. The grade 2 titanium cover is 0.034 inches thick and the fill port through hole diameter is 0.043 ± 0.001 inches. The class 100, grade 5 titanium ball measures 3/64 inches in diameter and is placed over the hole. An opposed electrode resistance weld configuration is used.

Since the interface resistance changes rapidly during projection welding, power feedback was chosen to control weld energy. We also used a dual pulse weld schedule with the first pulse set to breakdown the oxide layer on the titanium and the second to complete the weld. A direct current resistance weld controller that incorporates closed loop feedback to control the weld energy was used in this preliminary study. Since titanium has a very high electrical resistance, standard RWMA #2 material was used for both the upper electrode and the cover holder (lower electrode).

The three critical weld factors associated with nearly all resistance weld processes are power, electrode force and weld time. Obviously, there are many other factors that may affect weld quality, such as feature size, hold time and electrode geometry, so it's always a good idea to conduct a screening design of experiments (DOE) to develop a resistance weld process. This will help produce an optimal process window and identify the critical factors.

Table 1 shows the DOE factors and non-DOE (i.e. constant parameters) used for this initial 5 factor half-factorial DOE, which resulted in a total of 16 runs.

Weld Schedule	Constant	Low	High	Unit
Squeeze Time	100	-	-	ms
Electrode Force	-	4	6	lb
Pulse 1 Up	10	-	-	ms
Pulse 1 Dwell	-	5	15	ms
Pulse 1 Energy	-	0.35	0.65	kW
Pulse 1 Down	0	-	-	ms
Cool	10	-	-	ms
Pulse 2 Up	10	-	-	ms
Pulse 2 Dwell	-	10	30	ms
Pulse 2 Energy	-	0.75	1.25	kW
Pulse 2 Down	0	-	-	ms
Cool/Hold	100	-	-	ms

Table 1. DOE Weld Schedule Parameters and Values

Once in production, it's important to capture both individual and group data to control the process. In this investigation, modern weld management software was used to perform the DOE and collect all process data from the weld controller and store it in a central database. The software was also used to record the two response parameters. The first was variable data, namely the ball push-out force, while the second was attribute data, namely the welded ball's visual appearance.

DOE Analysis

The push-out force response was analyzed and ranged from a low of 5.7 lbs. to a high 43.8 lbs., with 'Pulse 2 Energy' and 'Pulse 2 Dwell' being the statistically significant factors. Not surprisingly, the highest push-out force occurred with the treatment that had all high side values in Table 1. In this analysis, it's assumed that push-out force is a good indicator for electrolyte retention because it implies a solid weld joint and a hermitic seal.

The visual response attribute data was analyzed and revealed 'Electrode Force' and 'Pulse 2 Energy' were significant factors. However, even though high side pulse 2 energy produced high push out forces, there was severe material expulsion. Figure 2 shows a typical high pulse 2 weld energy and low electrode force on the left and a low pulse 2 energy and high force on the right. In fact, all runs using low force and a high pulse 2 energy produced significant material "blow-out". Note that runs with low pulse 2 energy and high electrode force still had respectable push-out forces of around 21 lbs.

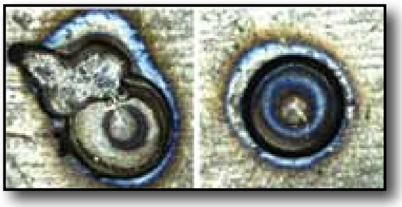

Figure 2. Projection Weld Top Views, Expulsion (left) No Expulsion (right)

Figure 3. Projection Weld Cross-section (35X magnification)

A cross-section of a low pulse 2 energy, high pulse 2 dwell time, and high electrode force is shown in Figure 3. Notice that the top of the spherical ball is flattened, due to the heat during the projection weld, and only projects 0.005 inches above the surface of the cover. Visual inspection seems to indicate that a hermetic joint was produced, but only a helium leak test would be able to confirm.

Waveform Signal Analysis

In addition to capturing summary weld data like peak and average voltage, power, current and resistance, comprehensive weld management software will leverage a weld controller's built-in monitoring capabilities by capturing the waveforms too. This allows a manufacturer to capture and analyze valuable waveform data, which along with modern signal analysis techniques, can be used to detect bad welds. Figure 4 shows the weld curves for the part exhibiting visual expulsion in Figure 2.

The voltage waveform clearly has voltage ripple during the second pulse dwell period, which differs markedly from the smooth exponential decay for parts without expulsion. In production, this failure mode could be detected without visual inspection, by using waveform pattern matching, a standard feature in high performance resistance weld software.

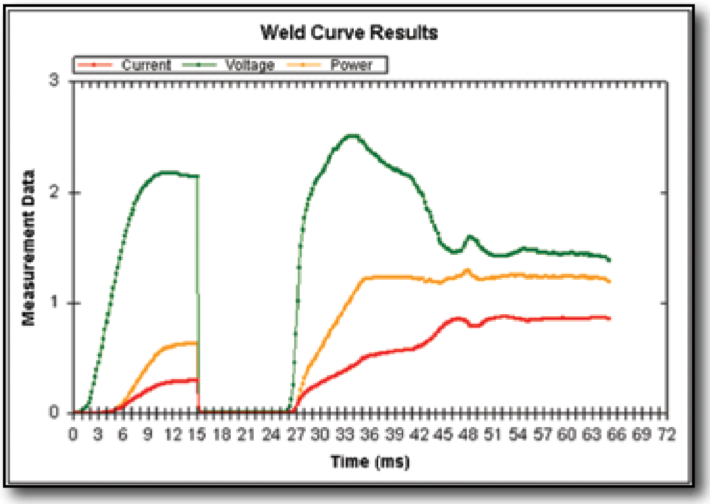

Figure 4. Projection Weld Expulsion Waveforms: Power (yellow), Current (red), and Voltage (green)

Conclusion

This article discussed the advantages to resistance projection welding and common joint configurations to realize them. A small scale resistance weld study was performed on a medical device battery cover and fill port ball to better understand the process. The preliminary study showed that pulse 2 energy, dwell time and force are important parameters. Further study would need to be done to confirm that high push-out force correlates with joint hermiticity. Weld monitoring signals, such as voltage, appear to have distinct signatures in the event of weld expulsion and could be used with modern weld management software to keep the process in control. Resistance welding is a low cost manufacturing method and can provide a robust weld joint in critical applications.

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