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Advances in Resistance Welding Technology Offer Improved Weld Quality and Reliability for Battery Manufacturing

Geoff Shannon
Miyachi Unitek Corp.

In the battery industry, the use of resistance welding for electrical connectivity and battery pack manufacture dates back many decades. The weld controls that provided the foundation for this market were Capacitive Discharge (CD) and AC welders. This technology remained largely unchanged for many years, and provided adequate weld quality for mainstream battery welding applications.

Recent global growth in both demand and diversity of battery products, with increasing emphasis on production quality, is driving the replacement of CD and AC resistance welding power supplies with the latest inverter and linear DC power supplies. High frequency inverters and linear DC welders both offer features generally not available on their CD and AC counterparts: closed loop feedback, fast rise times, 0.1 millisecond pulse adjustments, weld monitoring with limit setting plus a number of process tools.

The difference between open and closed-loop technology is that with open-loop the same energy is delivered for each and every weld with no adjustment for changes that occur in the weld set-up. In contrast, closed-loop inverter and linear DC make adjustments to the weld energy based on the starting resistance and how that resistance changes during the weld. This is significant as the amount of heat generated in a weld is directly related to the resistance between the two weld surfaces, and is also affected by the stack up of resistances of the complete circuit.

There are seven separate resistances, shown in Figure 1, that combine to form elements of the resistance profile. Each element will draw current from the weld pulse according to its size. With open-loop technology there is no compensation for variations that may occur due to material or plating composition, plating thickness, part fit-up, electrode position, gap spacing or electrode wear.

Inverters and linear DC have feedback control loops in the order of tens of microseconds meaning that this function can be completed many times during a weld lasting only 10 ms to 100 ms. A number of feedback modes can be offered and these are selected according to the likely resistance profile type of the weld. In most battery welding applications the weld is either flat-surface to flat-surface or a projection weld. In these cases, constant current and power are usually preferred.

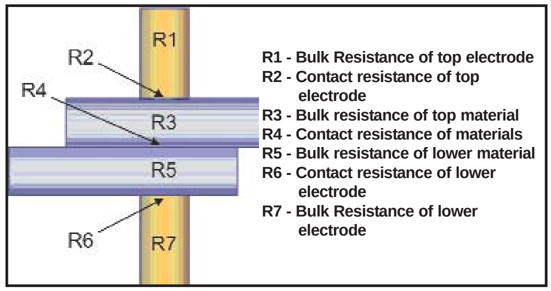

Figure 1. Indicates the seven resistances in a weld. The weld heat directly relates to the resistance stack up and specifically R4 between the weld interfaces. Variations in this stack up can be accommodated using inverters and linear DC power supplies.

A further benefit of closed-loop technology is that the weld can be monitored. For example, when welding in current mode the power supply adjusts the voltage according to I=V/R to maintain the same current level for each weld. An acceptable weld has a voltage waveform signature that can be defined. Once defined, limits can be placed around this waveform such that when an anomaly occurs this can be alarmed.

Resistance welding is used across many different battery types, but there are two main categories: large, lead-acid for automotive applications and the tab-and-pack connections for lithium and alkaline batteries.

Lead Acid Batteries

The manufacture of reliable, high-performance lead-acid batteries for use in demanding automotive, marine and industrial applications poses significant challenges. The welding application requires that a series of lead castings, called "tombstones," which constitute the cores of the individual battery cells, be joined. These lead tombstones must be linked together using consistent and precisely controlled weld nuggets in order to assure proper operation and long-life of the final battery assembly.

The welding challenge arises due to the high level of resistance variability that occurs based upon the age of the lead. These variations happen over a period of less than 72 hours, therefore, controlling batch parts according to age is not viable

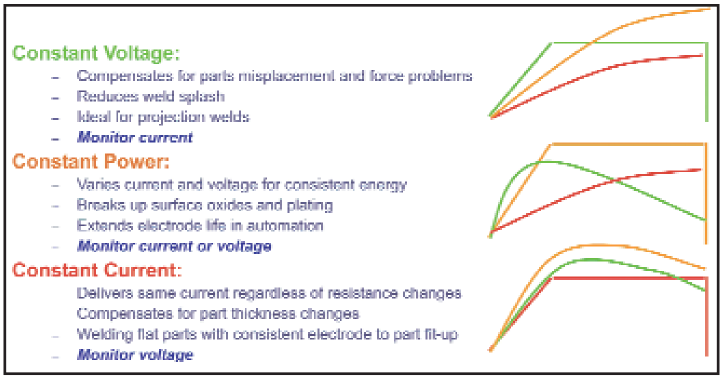

Figure 2. Three common feedback modes can be selected on inverter and linear DC power supplies. These are chosen based upon the type of weld, resistance profile and likely weld set-up variances.

in production. This resistance variation makes it very difficult to achieve consistent results with traditional AC resistance welding processes, which are also susceptible to current spikes and inherent variability in the welding process. Even the use of advanced AC weld controls, with more consistent secondary current output, is not sufficient; operators must continually adjust weld parameters to maintain acceptable welds.

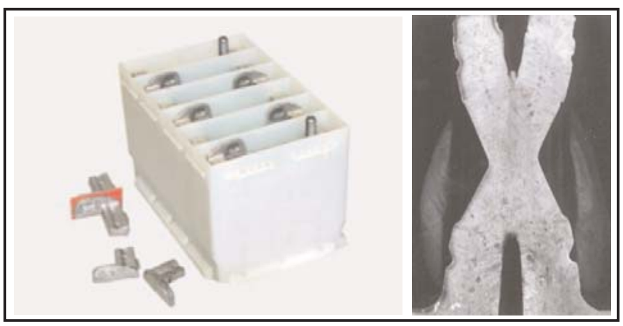

Figure 3. Resistance variability through the lead aging process requires continual adjustment of the process using AC controls. With inverter controls a single weld schedule can accommodate these dynamic variations and avoid weld defects such as porosity, cracking and a large heat affected zone.

The most effective approach to the unique challenges of lead-acid battery welding is to use advanced inverter (DC) solutions that combine precision controlled secondary power (V x I) with comprehensive monitoring and real time feedback mechanisms. By sensing and adapting for differences in resistance in the lead castings as well as other variations in the weld process (e.g. electrode wear, cabling, etc.), these systems can automatically maintain constant power and consistent heating profiles at the weld nugget. As a result, inverter controls using constant power feedback are able to deliver dramatically increased yields while simultaneously eliminating the inefficiencies and inconsistencies of operator-dependent process tweaking. Among the most significant benefits has been the expansion of the effective process window from only 15 minutes between schedule updates for AC controls, to as many as 72 hours without any necessary operator adjustments for the inverter.

Lithium and Alkaline Batteries

There are three key areas for inverter and Linear DC welding technology: welding tabs to button cells, increasing weld reliability for AAA/AA cells, and welding thicker or more conductive tabs for large capacity cells. To ensure an optimized weld for this large range of parts a high level of control and flexibility is necessary.

Aside from the open-loop nature of CD and AC controls a further limitation of these units is selection of the weld time. For CD welders this is typically three or four fixed length pulses, and for AC, the adjustment is half cycle, which is 8.3 ms. A key part of achieving high quality welds in these types of cells is having the capability of energy input control. Both inverter and linear DC power supplies have 0.1 millisecond time increments which offer the necessary resolution to optimize the weld time. They also feature a number of unique processing tools that improve welding such as pre-weld check, active part conditioning, envelope limits, force monitoring, displacement and the weld head.

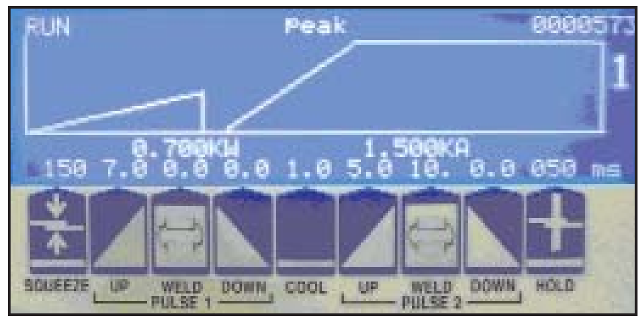

Figure 4. Inverter and linear DC power supplies can be programmed to 0.1 millisecond and 5A increments with upslope or downslope. CD welders have no such control with typically three or four fixed length pulses, and for AC, the time adjustment is half cycle, which is a minimum increment of 8.3 ms.

Pre-Weld Check

A very small pulse is used to confirm that the power supply senses a resistance in line with the 'usual' range. If this is not detected, the weld is aborted, avoiding weld issues such as part blow out.

Active Part Conditioning (APC)

Active Part Conditioning provides a means to normalize the resistance prior to the main welding pulse. In the past, has been achieved on CD welders by using a pulse that is nominally 15 percent of the main pulse. However, the resistance variation is not constant, therefore, a numerically fixed pre-welding pulse cannot accommodate such variation. APC uses a resistance value to weld to providing a consistent resistance for the main welding pulse independent of set-up or material variations.

Envelope Limits

The resistance welding process has four parts: initiation, where the electrodes begin to deliver power and the parts undergo partial heating; weld start, where the weld interface reaches melting point and the nugget starts to form; weld development, the nugget grows according to the power and time of the pulse; and weld completion, the nugget is fully developed, weld power is terminated, and the nugget solidifies still under the force of the electrodes.

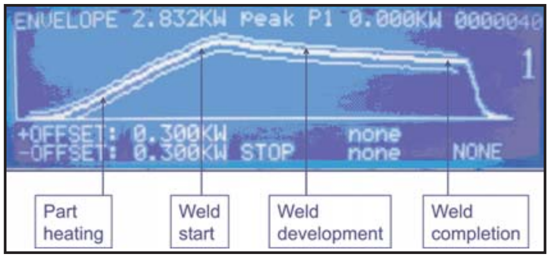

Figure 5. An envelope can be placed around a good monitored signal. This provides the benchmark against which all welds are compared, and with limits around the entire weld time pulse any deviations can be alarmed.

The weld can get out of control at any point in the process, however, the start of the weld is most important. The envelope function allows the user to pre-select a good weld monitor signal, and place suitable limits around that signature. In this case, the entire time duration of the weld is monitored, and if the envelope limits are exceeded the weld can be terminated.

Force Monitoring

The weld force is equally as important as weld current and time, therefore, it makes sense that this also should be monitored. By placing a load cell in the weld head, the force prior to welding can be monitored to ensure it does not drift out of preset limits.

Displacement

For many welds, a flat tab is welded to a terminal, however, with increasing tab thickness, projections are becoming more widely used. The collapse of the projections is a key weld quality indication and can be measured using a displacement sensor linked directly into the power supply. The sensor is mounted on the weld head with a displacement resolution up to 1 micron. Displacement measurement can also indicate if all the materials are present prior to welding, preventing weld blow outs, and untimely electrode changes.

The weld head

It is worth mentioning that weld head selection is equally as important as that of the power supply. Ultimately contact of the electrodes, and how the head imparts force and part follow-up are also key factors in the complete solution.

Summary

High demand for reliable, quality welds and the diversity of welding applications is driving the switch to these more advanced power supplies. Inverter and linear DC technology offer a means to increase control and quality of battery tab and pack welding. The closed loop technology, various feedback modes and process tools can accommodate a certain level of resistance variations in the weld caused by material, plating and fit-up.

Geoff Shannon has been with Miyachi Unitek for six years involved with resistance welding applications and product development and is currently in the position of product manager for all resistance products. Previous to this he spent around 14 years in laser materials processing industry involved with application development of laser products for cutting, welding and marking.

Contact Miyachi Unitek at info@muc.miyachi.com.