microJoining Solutions – microTips™
5563 Hallowell Avenue • Arcadia, CA 91007
Phone: 626-444-9606 • Fax: 626-279-7450 • Email: mjs@microjoining.com • Web: www.microjoining.com

Weld Quality Assurance for Laser and Resistance Welding

David Steinmeier

Introduction

Defining and measuring weld quality continue to be major issues for many manufacturing companies utilizing laser and resistance welding. This microTip provides guidance in defining and measuring laser and resistance weld quality.

Weld Quality Definition

Weld quality is a quantitative aspect of a product that ensures product functionality for our customers. Consider the following examples.

Weld Quality Example – Hand Drill

A hand drill uses a Li-Ion battery pack to provide portable power. Weld straps or "tabs" are laser or resistance welded to each cell to form the battery pack. The battery pack must have the longest possible life between charges. Therefore, the electrical resistance of the welded battery pack must be minimized. The battery pack must be capable of surviving multiple drops from waist high and from a ladder without the weld straps separating from the cells. The battery pack must also be capable of surviving day and night temperature changes when left outside. Finally, the battery pack must survive shipping vibration. To summarize, the weld quality metrics for a battery pack include:

- Electrical characteristics
- Impact or shock survivability
- Temperature cycling
- Shipping vibration

Weld Quality Example – Medical Device Catheter

Consider a medical device catheter that must be inserted into the groin and then threaded into the heart or brain to measure a physiological function or perform an intervention process. Laser or resistance welding attaches wires to the sensor or interventional device. The weld joints must survive compression, tension, bending, and tortuous path forces on their way to the catheter's end destination. Thus weld quality metrics for a catheter include:

- Electrical integrity
- Insertion and withdrawal forces
- Bending cycles at one or more angles
- Tortuous path cycles

Weld Quality Example – Automotive Sensor

Many automotive sensors contain round or flat lead electronic components welded to flat terminals. These sensors are subjects to thousands of temperature and vibration cycles when installed in your automobile. During over-molding the flow of pressurized plastic can shear a weld joint. Thus, the weld quality metrics for an automotive sensor include:

- Electrical integrity after over-molding
- Temperature cycling
- Vibration cycling
- Shipping vibration

Weld Quality Metrics

Depending on product functionality, weld quality metrics include but are not limited to:

Break Mode	Impact or Shock
Electrical	Mechanical Testing
Fatigue Cycling	Temperature Cycling
Hermeticity	Vibration
Humidity	Visual

Weld Quality Metric Conflicts

Following the "more is better" approach, many times the engineering, manufacturing, and quality assurance team arbitrarily includes weld quality metrics that do NOT represent product functionality. Visual weld quality metrics such as weld color, weld geometry, and weld flow are often added to the weld quality metrics and yet conflict with product functionality. In fact, trying to achieve visual "weld quality metrics" can result in degraded product functionality and unnecessary product scrap.

Weld Quality Measurement Task

The goal for the welding team is not simple. They must a) select welding process metrics that correlate with the selected weld quality metrics, b) optimize the welding process using the selected process metrics, and c) establish welding process metric limits that correlate with the weld quality metrics. Too often, the metrics selected for monitoring the welding process do NOT correlate with the weld quality metrics. This microTip will guide you through these three steps using the battery pack example.

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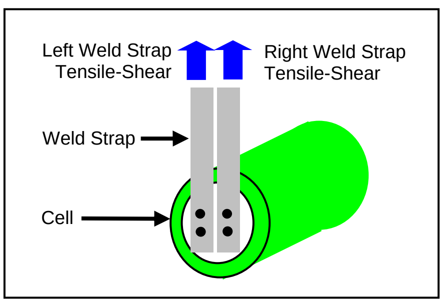
Selecting Welding Process Metrics

Selecting one or more welding process metrics is difficult because there is no certainty that the selected welding process metrics will correlate with the selected weld quality metrics. Reviewing the failure mode for each weld quality metric can help narrow the selection of welding process metrics and improve the probability of finding a correlation.

For the hand drill example, the predominant weld quality failure mode will be shearing of the weld joint between the weld straps and cells when the welded battery pack is subjected to the weld quality metrics of drop, vibration, and temperature cycling. This shear failure can be caused by welding process problems stemming from a) the lack of welding process optimization, b) an incomplete weld, and c) welding equipment problems. Therefore, we can use tensile-shear as the weld process metric for optimizing and monitoring the welding process.

When testing a resistance welded weld strap, the weld strap can be divided into left and right welds to see if the weld current polarity affects the tensile-shear. Dividing the weld strap is not necessary for a laser weld.

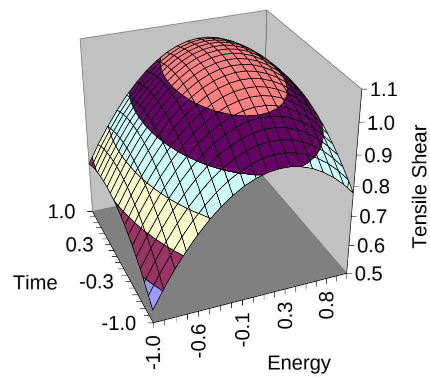


"No welds" and "incomplete welds" can be easily detected by non-destructive welding process metrics. For laser welding, we can use the laser's internal power meter, which measures a portion of the generated laser energy produced during the weld. However, the internal laser power meter does not represent the actual weld energy reaching the parts. Non-destructive welding process metrics for resistance welding include measuring the weld current and voltage, displacement and force envelopes, for both peak and average values.

Note that weld heat damage to the separator layer in Li-ion cells is only detectable by the weld quality metrics of temperature cycling and electrical testing of the welded pack. Separator damage is not detectable by any of the non-destructive welding process metrics.

Optimizing the Welding Process – Portable Drill

Maximize the welding process metric of tensile-shear using the Design of Experiment Process (DoE). Experience has shown that when welding a battery pack comprised of Li-Ion cells, a combination of high weld energy over a very short duration prevents separator layer damage and yet creates high tensile-shear. The combination of low weld energy over a long duration may produce acceptable tensile-shear results, but will damage the separator. The graph below depicts the surface response of tensile-shear over a range of weld energy and weld time.



Setting Limits

It is important to remember that the optimized welding process represents a very small slice in time. In the production environment, the cover glass protecting the laser focusing lens will become pitted with weld debris. Resistance welding electrode tips oxidize, become impregnated with part material, and "mushroom" in size. These changes over time negatively affect the weld heat. Thus one or more confirmations runs must be conducted to find the minimum tensile-shear value that will ensure that all weld quality metrics are met. During these confirmation runs, gather both destructive and non-destructive welding process metrics on a 100% or sampling basis. The results of the weld quality metric testing will determine the maximum lot size and will provide the minimum tensile-shear value for setting the welding process lower limit. Finally, run a correlation study between the tensile-shear data and all other non-destructive welding process metrics. For this battery pack example, only the welding process metric of tensile-shear correlated with all weld quality metrics.

Reference:

Laser and Resistance Welding – Process Validation Fundamentals-2.