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 Joint Testing Basics

By David Steinmeier

Weld Strength Testing

Achieving six-sigma production weld joint quality requires weld joint testing and a sampling plan. Developing a laser or resistance weld schedule also requires a weld joint testing method.

Non-destructive Test Methods

Post weld, non-destructive test methods for both laser and resistance welding include: hermeticity, visual inspection, weld geometry measurements, ultrasound, and X-Ray. Dynamic weld test methods include: part surface temperature.

Non-destructive Testing Problems

All non-destructive tests (NDT) do not measure weld strength. NDT testing relies upon establishing a strong correlation between NDT measurements with destructive measurements of weld strength such as tensile/shear or peel. The development and validation of NDT measurements with weld strength can often be costly and futile.

Visual inspection methods, including weld color, geometry, and material flow, don't correlate with weld strength. For a more detailed explanation on why visual inspection criteria do not work, download the microTip, Resistance Welding – Quality Assurance Issues, "Appearances are Deceiving". http://www.microjoining.com/microTip_Library.htm

Ultrasound, and X-Ray may or may not correlate with destructive measures of weld strength and can be difficult and expensive to employ except on a statistical sampling basis.

For resistance welding, dynamic weld current, voltage, displacement, and force measurements can provide valuable trend information, but still do not explain the source of variance in destructive weld strength tensile/shear or peel test measurements. For laser welding, dynamic temperature measurements of the molten weld puddle may or may not correlate with destructive weld strength.

Destructive Testing Methods

Commonly used destructive test methods for laser and resistance welds include: cross sections, failure mode, tensile/shear, and peel.

Cross Section Testing

Cross sections don't measure weld strength but are very useful for evaluating the robustness of the weld joint. Cross sections are particularly valuable when developing a new welding process. Cross sections can reveal brittle intermetallic layers, which may cause weld failures when the welded part is subjected to mechanical vibration, stress, and temperature cycling. Like ultrasound and X-Rays, cross sections can be difficult and expensive to use except on a sampling basis.

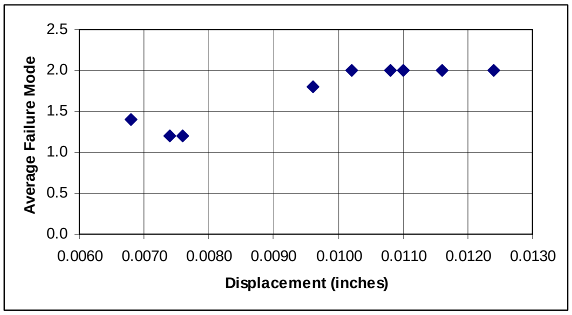
Failure Mode Testing

Failure mode testing involves assigning a subjective "Failure Mode Code" to the results of a tensile/shear or peel test. This is called "Attribute Testing" does not require a force gage. For many welding applications, failure mode testing may be "good enough" even though failure mode testing doesn't directly measure weld strength. In addition, the Failure Mode Code usually correlates quite well with one or more non-destructive dynamic resistance welding parameters such as weld current, voltage, displacement, or force.

It is important to separate the welded parts using a repeatable pulling action since changing the pull angle can change the results. The following simple example shows how the failure mode code results from a Design of Experiment (DoE) were used to develop a constant current resistance weld schedule for joining a copper wire to a tin plated terminal. Here are the assigned failure mode codes:

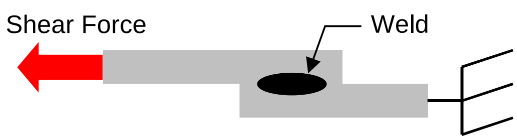
"0" = No visible copper wire mark on the terminal
"1" = Wire pulls off terminal, leaving a mark
"2" = Wire breaks off in front of weld

The graph on the next page shows the relationship between the measured peak weld displacement and the failure mode code for nine unique sets of welding conditions. From an application viewpoint, a code of "1" or more is more than sufficient for this application. Note that three data points provide a minimum failure mode code of 1. The remaining six data points provide a failure mode code of 2. Thus, any of these six operating conditions can be used for the optimized weld schedule.



Tensile/Shear Testing

Tensile/shear testing is the most common method of weld joint testing. It is easy to set up and is substantially less susceptible to minor changes in pull force geometry since a shear force is applied to the welded assembly in the same plane as shown in the figure below.



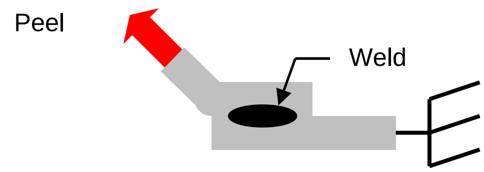
"Stress" is equal to shear force divided by the welded assembly's cross sectional area. Using "stress" helps to normalize tensile/shear results between welded assemblies with varying cross sectional areas. From a practical viewpoint, it is very hard to measure the effective cross sectional area, so most small-scale weld strength testing relies on just recording the peak force where the part breaks.

"Strain" is the change in length divided by the original, non-stretched length. "Strain" can provide an indication of part hardness. Measuring weld "Strain" is rarely used when conducting small-scale tensile/shear weld strength tests.

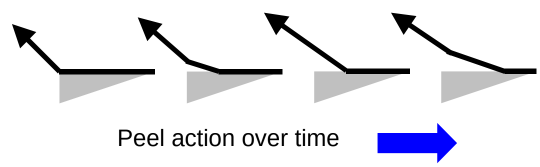
Tensile/shear testing requires a peak reading force gage, preferably a digital gage with analog or digital data output and a good set of non-slipping grippers. It is best conducted using a constant pull rate. Using long test parts reduces weld strength variations caused by small changes in pull geometry. Weld failure modes are very similar to those listed in the paragraph on Failure Mode Testing. Tensile/shear testing can mask the true weld joint strength if one or both parts break at a force lower than the weld joint.
Tensile/shear testing variances come from: a) variations in the weld contact area between parts, b) force gage repeatability and non-linearity, c) pull angle geometry changes, and d) variations in the displacement (indentation) surrounding the weld area.

Peel Testing

Peel testing offers the advantage of protecting a welded assembly involving one delicate part such as a solar cell with welded tabs. Tensile/shear testing tears the welded tab along with a chunk of solar cell. Thus, the weld joint strength cannot be measured using tensile/shear testing.



Peel testing applies force to a "narrow strip" of weld contact area. As peeling proceeds, this "narrow strip" breaks away, resulting in the peel force being applied to the "next narrow strip" of contact area.



Peel testing disadvantages include large weld strength variances due to variations in: a) weld joint contact area during peeling, b) peel geometry, c) length of the welded assembly, d) amount of the welded assembly in each gripper, and e) material properties of the welded parts such as brittleness.

The graph below shows the 90° peel test results for the same weld described in the Failure Mode Testing section. Note the lack of clear correlation between the displacement and the actual peel strength. This lack of correlation is due to the wire fracturing in the 90° bend radius. Thus the wire properties were tested, not the weld joint strength.