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Weld Optimization Metrics for Laser and Resistance Welding - David Steinmeier

Introduction

Laser and resistance welding processes are generally optimized using the tensile or peel strength of the weld. Maximizing tensile or peel strength sometimes degrades other product functionality requirements. Ensuring product functionality involves optimizing the welding parameters in a way that accommodates multiple, and at times, conflicting weld quality metrics.

This microTip uses laser and resistance welding examples to illustrate the opposing nature of many weld quality requirements.

What is Weld Quality?

Weld quality is that quantitative aspect of a product that ensures product functionality for our customers.

Weld Quality Measurement Classification

Weld quality metrics can be characterized in three different ways: a) Variable/Attribute, b) Destructive/Non-destructive, and c) Functionality.

Variable/Attribute

Variable weld quality metrics are continuous. Examples include dimensions such as weld spot diameter, depth, and width, and measurements such as tensile or peel strength. These metrics are also called "analog" measurements. *Attribute* weld quality metrics are qualitative and discrete. Think of an attribute as a "digital" measurement. For example, a scale of "1 to 5" represents no electrode tip sticking to severe electrode tip sticking.

Destructive/Non-destructive

Non-destructive weld quality metrics can be measured many times since the part is not destroyed in the measurement process. Destructive metrics can only be measured once.

Functionality

Ensuring product functionality typically involves balancing multiple weld quality metrics. Some are environmental in nature while other metrics are more electrical or mechanical. The following table provides a limited list of functional weld quality metrics.

Functionality	Type	Destructive
Break Mode	Attribute	Yes
Fatigue Life	Variable	Yes
Hermeticity	Variable	Possibly
Impact	Variable	Possibly
Peel	Variable	Yes
Shock	Attribute	Possibly
Temp Cycling	Variable	Possibly
Tensile/Shear	Variable	Yes
Weld Dimensions	Variable	Possibly
Vibration	Attribute	Possibly

Resistance Welding Example

A very small diameter tungsten-iridium wire and two nickel terminals comprise an automotive detonating device. Resistance welding is used to make an opposed weld at each wire end to each nickel terminal. Tungsten-iridium is brittle and has a very strong tendency to crack under weld pressure. There are two weld quality metrics: a) bond shear strength and b) no weld cracking in the weld area connecting the two welds. Optimizing the welding parameters to produce maximum bond shear strength causes weld cracking. A DoE revealed the conflict between these two weld quality metrics.

Figure-1 shows the Y-bar Marginal Means Plot for Bond Shear Strength. Observe that weld current is the primary variable responsible for bond shear strength. More weld current equals more Bond Shear Strength. Upslope Time, Weld Time, Force, and Electrode alloy have minimal effect on the bond shear strength.

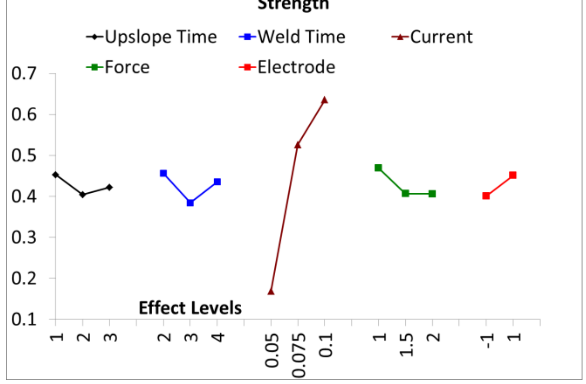

Figure-1: Y-bar Marginal Means Plot of Bond Shear Strength

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Figure-2 shows the Marginal Means Plot for Weld Cracking. In addition to the weld current, the Upslope Time, Weld Time, and Force have a significant impact on weld cracking. Electrode type has less impact on weld cracking.

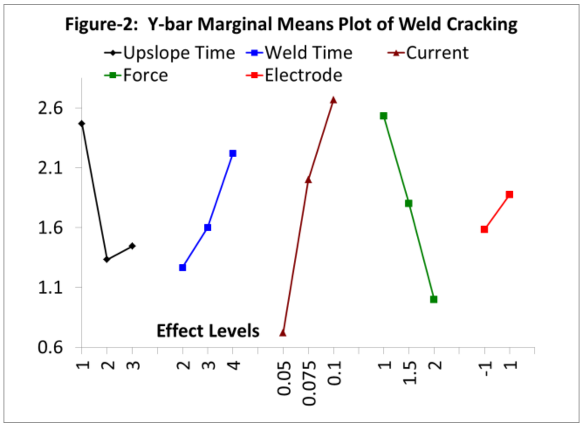

Figure-2: Y-bar Marginal Means Plot of Weld Cracking

Mathematically optimizing for maximum bond shear strength while minimizing weld cracking results in a set of welding parameters that utilize:

1. Maximum Upslope Time
2. Minimum Weld Time
3. 75% of maximum Current
4. Minimum Force.
5. Electrode Alloy "-1"

A statistically significant number of samples confirmed the optimized welding parameters in terms of meeting both weld quality metrics.

Laser Welding Example

A small diameter 316L stainless steel capsule and cap comprise a sensing device. Laser welding is used to seam weld the cap to the capsule. There are three weld quality metrics: a) burst strength b) break mode, and c) voids in the finished seam weld. A DoE revealed that achieving the maximum break mode value conflicted with achieving the maximum burst pressure and no voids in the weld junction.

Figure-3 shows the Main Effects Plot for the Break Mode. Observe that increasing the Offset increases the break mode value. Increasing the Voltage produces an inverted curve.

Figure-4 shows the Main Effects Plot for the Burst Pressure. Observe that increasing the Offset increases the burst pressure to a peak. Additional Offset decreases the burst pressure. Increasing the Voltage also produces an inverted curve.

Figure-5 shows that increasing the Offset or Voltage past "0" produces voids.

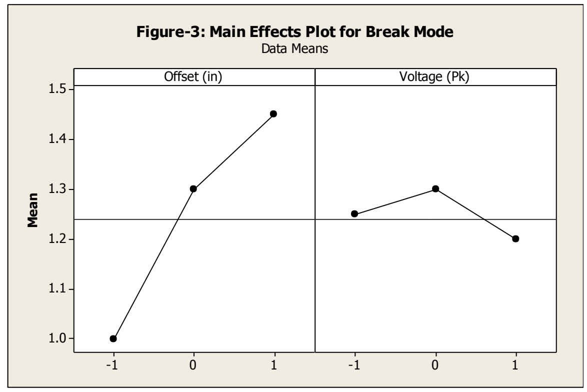

Figure-3: Main Effects Plot for Break Mode

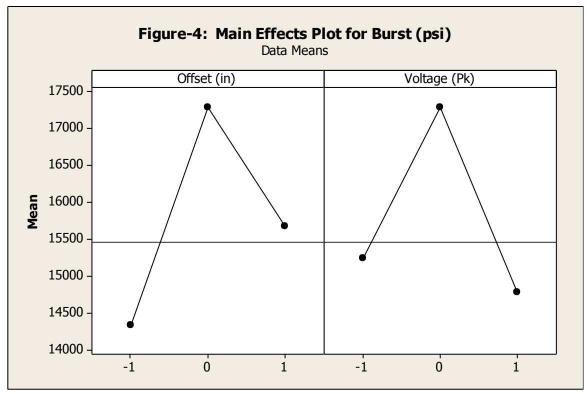

Figure-4: Main Effects Plot for Burst (psi)

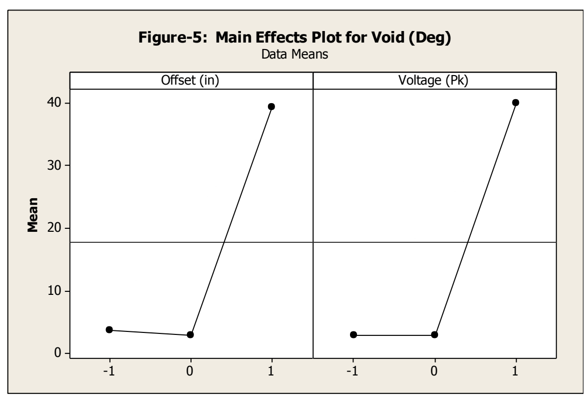

Figure-5: Main Effects Plot for Void (Deg)

The optimized welding parameters represent Offset and Voltage parameters with a "0" value.

Conclusion

Maximizing the tensile or peel strength weld quality metrics alone may not ensure a product that survives other weld quality metrics such as weld cracking, break mode, fatigue life, temperature cycling, or shock and vibration. Use the DoE process to help resolve weld quality metric conflicts.