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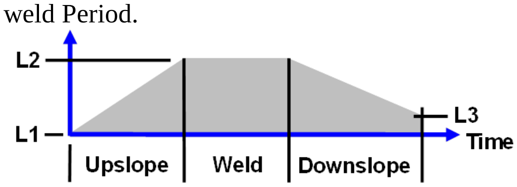
Upslope and Downslope Use in Resistance Welding - David Steinmeier

Introduction

Upslope represents a controlled increase in the weld current, voltage, or power from a low level (L1) to a high level (L2). Upslope occurs before the Weld Period.

Downslope represents a controlled decrease in the weld current, voltage, or power from a high level (L2) to a low level (L3). Downslope occurs after the weld Period.



Modern power supply technology such a Direct Current (DC) or High Frequency Inverter (HFI) offers the user the ability to precisely control the level and dwell time for each period. Non-feedback controlled power supply technology such as Stored Energy (Capacitive Discharge) does not offer high resolution control over these periods.

Why use Upslope?

There are three major reasons to use upslope during the welding process:

- Match the rate of collapse of the parts to the rate of heating produced by the weld current.
- Maintain a constant weld current density.
- Prevent weld splash and electrode tip sparking.

Materials Responsive to Upslope

Upslope is best applied to electrically and thermally resistive materials such as iron, nickel, nickel alloys, and stainless steel. These materials do not rapidly dissipate the weld heat generated within these materials.

Materials Non-responsive to Upslope

Conversely, applying upslope to electrically and thermally highly-conductive materials such as copper, copper alloys, brass, and brass alloys is not very effective. These conductive materials can prevent the parts from reaching a bonding temperature due to the rapid dissipation of weld heat within the parts when conductive parts are slowly heated with an upslope profile.

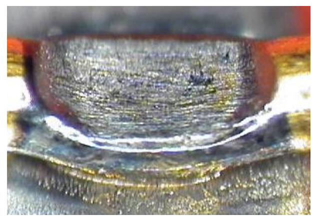
Upslope Applications

There are six primary applications for the use of upslope:

- Hard parts
- Plated parts
- Irregularly shaped parts
- Thermally sensitive parts
- Projections
- Weld head with poor follow up

Upslope – Hard Parts

Materials containing carbon, chromium, and molybdenum are difficult to weld. These hard materials tend to collapse at a slower rate compared to nickel or soft nickel alloys. Using a weld pulse with insufficient upslope can result in uncontrolled weld splash, weak welds, sparking, and damaged electrode tips.



Match the rate of part collapse by slowly adding upslope to the weld pulse profile to prevent or reduce weld splash and sparking. This photo shows the effect of using upslope to weld a hard, gold-plated nichrome wire to a tin-plated steel alloy terminal.

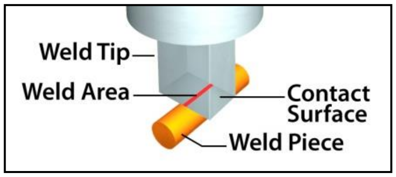
Upslope – Plated Parts

Nickel and tin plating are often used to protect iron, brass, and copper parts from oxidizing. The plating layer is not uniformly distributed. Corners on flat parts tend to have thicker plating compared to the middle section of a flat part. Even the plating on round parts can be unevenly distributed. The weld current flows through these thicker sections of the plating first. If the weld current profile does not include upslope, there is a strong possibility of occurrence of weld splash, sparking and electrode tip sticking to the parts. Using upslope allows the plating layer to compress uniformly and thin out across the parts. Upslope can also help to reduce electrode tip sticking to the plating.

It is important to note that upslope displaces and thins out plating, but does not remove the plating. The plating may create a brittle intermetallic with the base material. A thin intermetallic layer provides more resistance to temperature, shock, and vibration.

Upslope – Irregularly Shaped Parts
Prior to welding, round-to-round and round-to-flat parts have small initial contact area. Applying a fast rise weld current pulse will result in creating uncontrolled weld splash and sparking. By utilizing upslope, the contact areas between the electrode tips and parts and between the parts can be increased in a controlled manner. With the proper upslope, the weld current density will remain constant throughout the entire welding process.

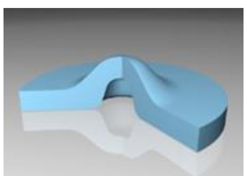
The adjacent drawing shows the very small contact area between a rectangular electrode tip and a round wire prior to the start of weld current.



Upslope - Thermally Sensitive Parts
Welding applications involving parts that are surrounding by a glass seal or are bonded to the top of a glass substrate may require the use of upslope to prevent cracking the glass material.

Passing a rapidly rising weld current flowing through a molybdenum pin surrounding by a glass seal, can cause the pin to expand too quickly, cracking the surrounding glass. Using this same "fast pulse" to weld Invar or Inconel interconnects onto silver plated contacts deposited on the top of silicon or gallium arsenide solar cells can also cause the delicate substrate to crack. Use upslope is to slow the rate of weld temperature increase, thus preventing the glass seal or substrate from cracking.

Upslope – Projections
Projections are small indentations into one of the parts that will be resistance welded. Projections help create a uniform weld heat balance between parts with different thermal loads. Because the projection confines the weld current to a small starting area, upslope must be used to gradually increase the weld current as the projection collapses. Match the rate of weld current increase with the rate of projection collapse to prevent weld splash and sparking.



Upslope – Poor Weld Head Follow Up
The weld head clamps the parts together and provides a path for the weld current to flow through the electrodes to the clamped parts. The ideal weld head has "infinite inertia follow-up capability". Inertia follow up is the ability of the electrodes to stay up against the parts as the parts become soft and melt. If the moving parts of the weld head contain too much mass to provide rapid follow up, weld splash and electrode damage can occur.

One way to compensate for a weld head with poor inertia follow up is to use upslope. Match the rate of weld current increase with the rate of electrode follow up to prevent weld splash and sparking.

Why use Downslope?
There are two major reasons to use downslope during the welding process:

- Prevent cracking in metal-to-glass seal and metal-on-glass substrate welding applications.
- Prevent solidification cracking in alloys containing metals with disparate melting temperatures.

Downslope – Thermally Sensitive Parts
Instantly terminating the weld current flowing through a molybdenum pin surrounding by a glass seal can cause the expanded pin to shrink too quickly, thus cracking the surrounding glass. Instantly terminating the weld current when welding Invar or Inconel interconnects onto silver plated contacts on the top of silicon or gallium arsenide solar cells can also cause the delicate substrate to crack. Use downslope is to slow the rate of weld current decrease to prevent the glass seal or substrate from cracking.

Downslope – Prevent Solidification Cracking
Metal alloys containing elements with a wide range of melting temperatures are susceptible to solidification cracking. The high temperature element solidifies before the low temperature element, leaving the liquid low temperature element in the grain boundaries. The stress of fast cooling will induce cracking along the grains before the liquid low temperature element can solidify. Use downslope to slow down the cooling rate. A good example of an alloy susceptible to solidification cracking is Inconel-601.