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Small Scale Resistance Welding – Electrode Tip Heating Issues

Introduction

Passing weld current through an electrode produces heat within the electrode body, tip, tip-to-part interface, parts, and part-to-part interface.

With each subsequent weld, the residual electrode tip heat increases before stabilizing at some average value determined by the welding rate and weld energy. This residual heat is difficult to dissipate because of the electrode and electrode holder configurations used in small scale resistance welding. Residual electrode tip heat can be a large problem in automated welding environments where the welding rate can reach one weld per second or faster. Residual tip heat is generally not an issue with manual welding due to the slow welding rate.

This microTip discusses the problems created by residual electrode tip heat, factors responsible for the heating problems and how to mitigate these problems.

Residual Electrode Tip Heat Problems

Residual electrode tip heat can cause the following small scale resistance welding problems:

- Increased part deformation
- Part cracking
- Rapid tip oxidation
- Rapid part material/plating build up on the tip
- Reduced weld strength
- Severe tip-to-part sticking
- Severe tip geometry wear
- Shorter tip life

Factors Responsible for Tip Heating Problems

There are three primary factors responsible for residual electrode tip heat: a) electrode design, b) welding rate, and c) electrode cooling method.

Electrode Design

Electrode tip geometry and material and electrode shank geometry and material strongly affect tip heat generation and dissipation. Welding high resistivity metals such as platinum, nickel, and steel requires high conductivity electrode materials made from special copper alloys, which minimize residual heat build up in the electrode tip. Most of the weld heat comes from the part-to-part interface and the bulk resistance of the parts.

Welding low resistivity metals such as brass, copper and silver requires highly resistive electrode materials made from copper-tungsten, molybdenum, or tungsten. These electrode materials generate extra heat, which flows into the parts to help make the weld. It is important to note that while the electrical resistivity (ρ) of molybdenum and tungsten are virtually identical, their thermal conductivity values are different. Given identical electrode geometry and weld current, both materials generate the same power (watts). However, the tungsten electrode tip reaches a higher temperature than the molybdenum tip due to the higher thermal conductivity (k) of tungsten. This difference in tip heating can strongly affect the welding results. Compare the resistivity and thermal conductivity values in the following table. Be aware that the resistivity increases while the thermal conductivity decreases with temperature.

Material	Resistivity (μΩcm)	Thermal Conductivity (W/mK @ 25°C)
Copper	1.72	401
Molybdenum	5.5	138
Tungsten	5.4	173

To minimize residual tip heat when using resistive tips, make the tip area large in relation to the tip length. To dissipate residual tip heat, braze the resistive tip onto a RWMA-2 beryllium-copper shank as shown in the above figure. For a comprehensive discussion of electrode design, retrieve the microJoining Solutions microTip on Electrode Design for Small and Miniature Scale Resistance Welding.

Welding Rate

The welding rate is the second most important factor affecting residual electrode tip heat. Automated welding stations utilizing molybdenum or tungsten electrode tips typically show an increase in tip temperature with each new weld. Faster welding rates produce higher peak temperatures with each new weld. In some cases, the tensile or peel strength follows the same temperature pattern.

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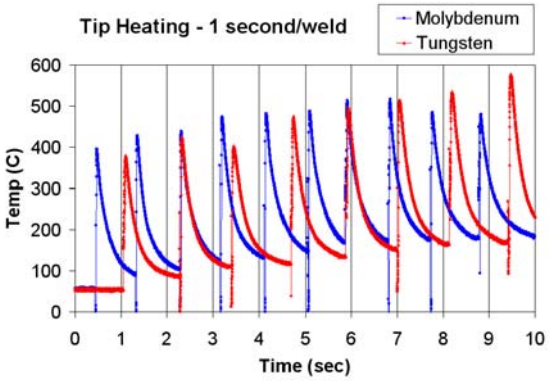
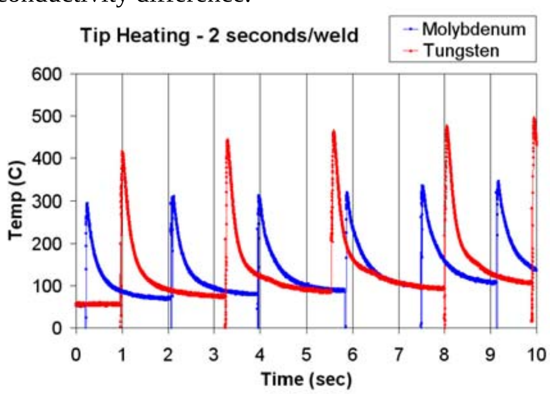
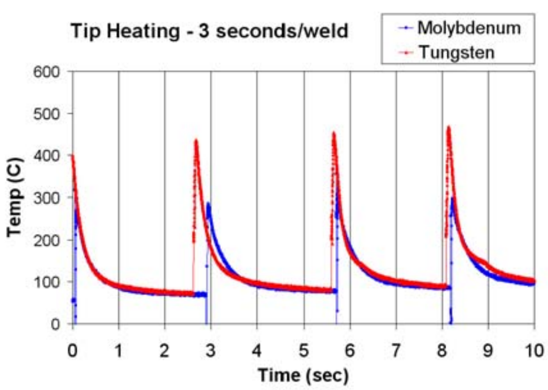
The weakest weld occurs at the first weld and increases in strength with the succeeding welds. Unfortunately, so does the electrode tip sticking. The following graph shows tip heating for both molybdenum and tungsten at an approximate welding rate of 1 weld every second.



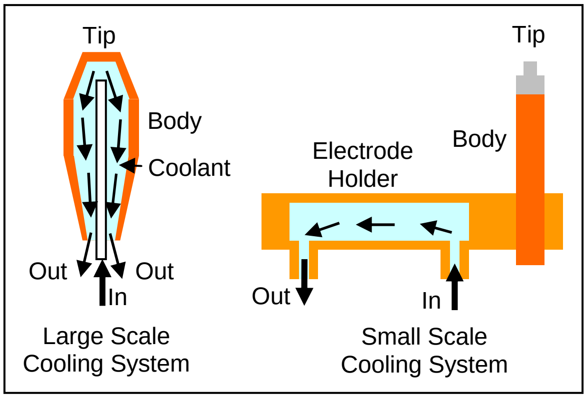
Slowing the welding rate reduces the peak tip temperature and allows the tip to reach a lower average operating temperature. The next two figures show welding rates of approximately 2 and 3 seconds between welds. At 1 weld every 3 seconds, there is very little increase in tip temperature weld-to-weld. Note the difference in peak temperature between the molybdenum and tungsten due to the thermal conductivity difference.





Electrode Tip Cooling

Small scale resistance welding electrodes are difficult to cool because the small electrode shank diameter of 3 to 6-mm precludes circulating water or coolant through the shank to remove the heat buildup in the tip. Because of this limitation, most small scale welding applications use a special electrode holder with fluid cooling capability. Electrode holder cooling has some effect on reducing the average electrode shank temperature, but minimal effect on reducing peak tip temperature. The figure below shows the difference in coolant flow between small and large scale resistance welding electrodes.



Air cooling is only partially effective at reducing the average tip temperature because of the small electrode tip and shank areas. Cooling typically occurs when the electrode is resting between welds. Vortex cooling creates a stream of very cold air that can be directed onto the electrode tips, but suffers from same limited cooling area constraints and requires sound abatement due to the vortex noise.

Mitigation Techniques

The simplest electrode tip heating mitigation method is to weld at a slower rate. If using a slower welding rate is not acceptable, then experiment with automatically reducing the weld current slightly for each subsequent weld. Measure the corresponding weld strength to validate the systematic step-down in weld current.

Use the electrode design shown on Page-1 to minimize tip heating. Avoid using long electrode shanks of copper-tungsten, molybdenum, or tungsten, since these materials produce large amounts of residual heat. Use coolant and air cooling only when absolutely necessary.