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Electrode Design for Small and Miniature Scale Resistance Welding
By David Steinmeier

Introduction
Proper electrode design is critical for achieving consistent weld quality in the world of small and miniature resistance welding. Each welding application requires the correct electrode material, tip profile, and shank profile to ensure consistent weld quality, minimum electrode sticking, and maximum electrode life.

Begin with the Application
To create the proper electrode design, you must begin by carefully reviewing your application. Three application factors determine your electrode design:

- Part base metal
- Part plating type and thickness
- Part weld geometry

Part Base Metal
Most small and miniature scale resistance welding applications involve welding one metal alloy to a different alloy. These "mixed metal" applications may require the use of two different electrode materials. An additional problem arises when a part is a "combination" material. Many axial electronic component leads have a steel core, followed by a copper clad layer, followed by tin plating. In most cases, the electrical conductivity of the *part base metal* determines the electrode material.

Low conductivity (high resistivity) metals such as beryllium-copper, platinum, nickel, and steel require high conductivity electrode materials made from special copper alloys. The high electrical conductivity allows weld heat to build up at the part-to-part weld interface while minimizing heat build up in the electrode tip.

High conductivity metals such as copper, some copper alloys, and silver require low conductivity electrode materials made from copper-tungsten, molybdenum, or tungsten. The electrode tip generates extra heat, which flows into the part-to-part interface, to augment the low interface weld heat.

Here is a partial list of small and miniature scale application metals and their recommended electrode materials. For a more detailed list, contact the American Welding Society (AWS) at www.aws.org.

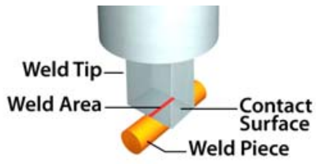
BASE MATERIAL	ELECTRODE MATERIALS		
	RWMA	COMPOSITION	CONDUCTIVITY
Be-Cu Nickel Platinum Stainless-Steel Titanium	-2 or -3 or Glidcop	Cu/Cr Cu/Co/Be Cu/ Al_2O_3	High
Brass Bronze	-11	Cu/W	Moderate
Copper Copper Alloys Silver	-13 or -14	W Mo	Low
Al_2O_3 Aluminum Oxide Be Beryllium Co Cobalt	Cr Chromium Cu Copper Mo Molybdenum	W Tungsten	

Part Plating Type and Thickness
Plating causes electrode tip sticking and reduces electrode life. Use the thinnest plating possible. Plating such as solder, tin, and zinc have low electrical conductivity, which dictates the use of RWMA-2, -3, or Glidcop electrode materials. Over time, tin, solder, and zinc plating alloy with these copper based electrode alloys, fouling the tips and degrading the weld quality. Reduce electrode tip contamination from these plating materials by:

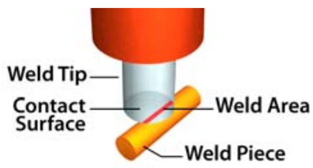
- Experimenting with Cu/W, Mo, and W electrode tips. Mo and W do not easily alloy with most plating materials.
- Making the electrode tip area large in relation to the actual weld area contact. A larger electrode tip mass operates at a lower average temperature, thus reducing electrode tip sticking.

Part Weld Geometry
The electrode tip design should ensure a constant contact area between the tip surface and the part regardless of the electrode-to-part position.

It is best to use a rectangular electrode tip to weld round-to-round or round-to-flat parts.



Avoid using a round electrode tip since the contact area will change, depending on the electrode-to-part position.



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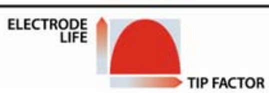
Electrode Design Factors

Good electrode design requires optimizing the following factors for maximum life in relation to the actual part weld geometry. Minimal electrode-to-part sticking correlates with maximum electrode life. Note that the relationship between electrode tip factors and electrode life is non-linear.

ELECTRODE LIFE / TIP FACTOR CURVE	TIP FACTOR
	AREA CONDUCTIVITY COOLING HARDNESS
	LENGTH WELD CURRENT DENSITY
	WELD PRESSURE

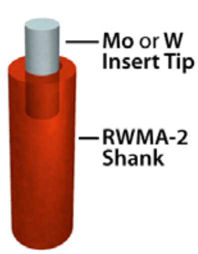
Electrode Tip Area

Use a tip area that is larger than the actual contact tip-to-part weld area. The non-contact tip area dissipates the waste weld heat, lowering the average tip temperature, which in turn increases tip life.

Electrode Tip Conductivity

When utilizing low conductivity electrode tips made from Cu/W, Mo, and W, silver braze these tip materials to a RWMA-2 or Glidcop shank to increase the absorption of waste weld heat. Avoid using long solid rods of Mo and W at weld currents above 1 KA and high weld duty cycles. Long, small diameter, low conductivity electrode rods generate a lot of waste heat, which then flows into the tip and reduces electrode life.

Also, avoid using Mo and W tips that are pressed into a RWMA-2 or Glidcop shanks. Under high weld current and duty cycle operating conditions, the electrical resistance between the shank and tip increases over time, negatively affecting the weld quality.

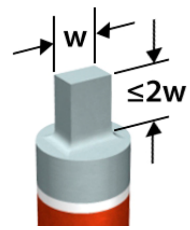


Electrode Tip Hardness

Utilize Cu/W, Mo, and W in place of RWMA-2, -3, and Glidcop to improve overall mechanical strength and durability when designing very small electrode tips. Welding round-to-round or round-to-flat parts can be very brutal on electrode tips made from RWMA-2 or Glidcop. These soft electrode materials grove rapidly, which changes weld quality. Consider using a pre-grooved electrode tip shape to reduce electrode wear and extend electrode life if your process control capability can maintain the groove.

Electrode Tip Length

Most electrodes are designed with long tips in relation to the tip area. This design logic assumes that the tip can be economically resurfaced many times before the entire electrode is replaced. In reality, weld quality decreases very rapidly with increasing tip length. Keep the tip length less than two times the largest tip width or diameter.



Electrode Tip Weld Current Density

An electrode tip can only accommodate a finite amount of weld current through its tip area. Severe electrode sticking, tip area deformation, and tip length bending are obvious signs of excess weld current density in relation to the tip geometry.

Electrode Tip Weld Pressure

There is an optimum weld pressure for each application. Insufficient weld pressure causes electrode degradation by spitting out pieces of the electrode tip and parts. Excessive weld pressure mechanically deforms the electrode tip. Too little or too much weld pressure negatively affects weld quality.

Conclusion

Good electrode design is a series of compromises that can only be verified by performing an electrode life test under real production operating conditions.

Acknowledgments:

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