



METALCUTTING
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SELECTING RESISTANCE SPOT WELDING ELECTRODE MATERIALS

Robotic welding and resistance spot welding machines are among the most essential automation tools in today's industries.

For instance, in automotive production assembly, they are commonly used to join everything from wire harness to battery assemblies. However, these machines—or more accurately the electrodes they use—are often the culprits in slow cycle times and inefficient production lines.

This guide reviews the range of resistance spot welding electrode materials and their properties, and highlights some of the electrode materials and alloys engineered to specifically address these common problems.

Additionally, we identify electrode materials with the proper thermal conduction, electrical resistivity, and reactivity (to avoid alloying) for many resistance spot welding applications.

Common resistance spot welding electrode issues include:

#01 IMPERFECT OR WEAK WELDS

#02 IMPROPERLY LOCATED WELDS

#03 ELECTRODE TIP STICKING

#04 ELECTRODE ALLOYING WITH WORKPIECE

NOTE

This guide does not attempt to present the many material grading schemes and systems, trade names, and alloyed combinations, which are the property of their respective owners.

A close-up photograph of a resistance spot welding process. Two metal pieces are being pressed together by a large, dark, curved electrode. A bright, intense orange and yellow light emanates from the point of contact, with numerous long, curved sparks flying outwards. The background is slightly blurred, showing industrial machinery and a safety fence.

RESISTANCE SPOT WELDING BASICS

Resistance spot welding is commonly used to join several metallic materials and sheets of different thicknesses together without large deformations.

Advantages of this process include:

- Allowing employees to avoid
- dangerous working conditions
- Cost efficiency
- Dimensional accuracy
- Reliable production

To understand what electrode materials are optimal for your resistance welding application, it is necessary to have a basic understanding of how the process works.

Essentially, a welding current is applied to a workpiece via electrodes, usually located on both sides of the lap joint.

One or both electrodes move and transmit force to the workpiece by pressing the welded surfaces together; conducting the welding current to the workpiece; and finally, cooling the weld and its environment to produce single, spot-like welds (or nuggets).

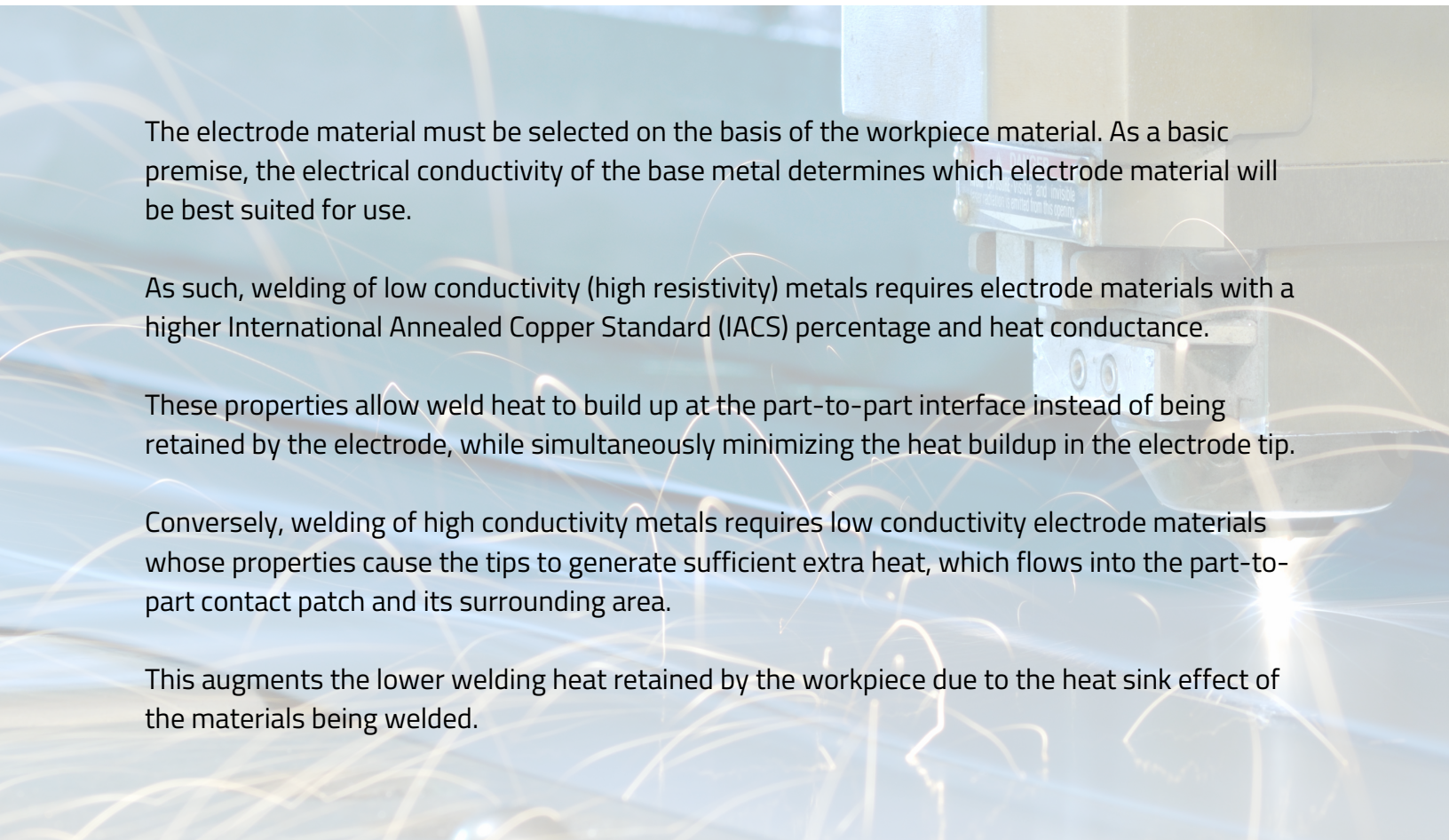
SELECTING ELECTRODE MATERIALS

Integral to the resistance welding process are the electrodes through which the welding current is directed. In simple terms, the role of a resistance welding electrode is to:

Supply a high welding current to the weld

Apply a high load voltage to the weld

Cool down the surface of the weld



The electrode material must be selected on the basis of the workpiece material. As a basic premise, the electrical conductivity of the base metal determines which electrode material will be best suited for use.

As such, welding of low conductivity (high resistivity) metals requires electrode materials with a higher International Annealed Copper Standard (IACS) percentage and heat conductance.

These properties allow weld heat to build up at the part-to-part interface instead of being retained by the electrode, while simultaneously minimizing the heat buildup in the electrode tip.

Conversely, welding of high conductivity metals requires low conductivity electrode materials whose properties cause the tips to generate sufficient extra heat, which flows into the part-to-part contact patch and its surrounding area.

This augments the lower welding heat retained by the workpiece due to the heat sink effect of the materials being welded.

CHARACTERISTICS OF HIGH CONDUCTIVITY ELECTRODE MATERIALS

Materials such as pure copper, copper cadmium, copper chromium, and other non-refractory copper alloys (considered Class 1 and 2 electrode materials under ISO 5182) are commonly used for high conductivity electrodes. This is due to the materials' optimal electrical and thermal conductivity, corrosion resistance, metal-to-metal wear resistance, and appearance.

Notably, precipitation-hardened alloys such as chromium copper (CrCu) can sometimes cause an increase in electrode hardness and a reduction of electrical conductivity. This is due to repeated heat cycling, which can result in further diffusion of the precipitates into the copper matrix. In addition, precipitation-hardened electrode materials can contaminate or become alloyed with certain workpiece materials, causing the electrode to prematurely fail.

Alumina-dispersed copper has been suggested as an alternative to precipitation-hardened copper alloys, due to its ability to maintain initial engineered hardness and electrical conductivity. Tests have shown that deterioration of alumina-dispersed copper due to repeated heating is less than that of precipitation-hardened alloys.

NOTE

Tungsten is more likely than molybdenum to break from heat shock. Therefore, in circumstance where tungsten electrodes show evidence of cracking the shot cycle, molybdenum may be preferable. However, molybdenum oxidizes more rapidly than tungsten. Process engineers need to assess conditions to determine whether heat-related cracking or oxidation would jeopardize electrode life more greatly.

CHARACTERISTICS OF LOW CONDUCTIVITY ELECTRODE MATERIALS

Low conductivity electrode materials include refractory metals such as tungsten, molybdenum, and certain refractory metal alloys, considered Class 3 electrodes under ISO 5182.

Among low conductivity electrodes, tungsten and molybdenum materials have higher temperature strength and are far more resistant to unwanted alloying with workpiece metals.

Tungsten (W) has the highest melting point 6192°F (3422°C) among metals, and it maintains excellent hardness at even the highest temperatures. It begins oxidation from about 752°F (400°C) through W3O, WO2, W2O058; from about 1292°F (700°C) it forms WO3 and oxidizes rapidly. In addition, the resistance of W is high ($5.5 \times 10^{-8} \Omega m$).

Molybdenum (Mo) has a high melting point and excellent mechanical strength at high temperatures. It oxidizes rapidly above 932°F (500°C) and changes to MoO3 of white gray above 1202°F (650°C). The resistance of Mo is high ($5.7 \times 10^{-8} \Omega m$).

Both W and Mo have excellent mechanical strength at high temperatures. This makes them optimal electrode material choices when the heat load on the electrode is high, such as with high current and short shot cycle.

Despite their optimal material properties, there are some drawbacks to working with pure W or Mo electrodes. For example, if the workpiece is a plated metal, the process will need to be engineered to reduce depositing and sputtering.

Another general concern is the inevitable negative oxidative process of any high temperature, normal atmosphere operation. In this scenario, it is important to engineer an opportunity in the process cycle for the electrode to cool down as much as possible to control the inevitable oxidative consumption.

ALLOYS: THE BEST OF BOTH WORLDS

Where pure tungsten and molybdenum may not be ideal, copper tungsten and silver tungsten (CuW and AgW, respectively) offer an alternative. They combine high temperature strength and high electrical conductivity to create a superior electrode material. These alloys are produced using powder blending and then infiltration and sintering in batches, versus being a continuous drawn product.

Copper tungsten (CuW) is available in various composition ratios and is very widely used when spot welding high conductivity metals such as copper wire or foil. Here, heat is generated mainly within the refractory electrode tip and then conducted into the materials to be joined.

Alloys of AgW are also produced in different composition ratios and are ideal for welding stainless steels and other nickel-based alloys. That is because silver is hard to alloy with iron (Fe) and nickel (Ni). Interestingly, copper contamination has been known to cause short-circuits in certain circumstances. As a result, AgW is often used in conditions where the corrosion resistance of silver is beneficial. However, if low cost is a top priority, AgW may not be the best choice due to the fluctuations in market price of the respective silver content.

Several other unusual but significant electrode materials are available for use when conditions require electrodes to maintain shape without the various negative consequences of oxidation. An example is silver tungsten carbide (AgWC), where the tungsten carbide (WC) provides superior oxidation resistance.

However, WC is a poor electrical conductor and difficult to machine into shape; therefore, it is not commercially used by itself as a spot welding electrode. Heavy tungsten alloys, which are varyingly comprised of W, Fe, Ni, and Cu (depending on the manufacturers and their respective grades), are an alternative material with excellent oxidation resistance and comparably better machinability than WC.

MAKE THE RIGHT CHOICE

Proper electrode material selection, design, and construction is essential to ensuring consistent weld quality, minimum electrode sticking, and maximum electrode life. It requires not only the correct materials and correct tip and shank profiles, but also proper bonding in the manufacture of the electrode itself.

Without the right design and construction, end production can be significantly impacted by inefficiency, weak welds, and defective bonding between the materials that comprise the electrode itself.

To perform satisfactorily, the electrode material must:

- Have good electrical and heat conduction properties that differ significantly from those of the materials to be welded together
- Not form alloys with the base material(s)
- Endure compressive force during welding and be hard even when hot
- Have sufficient strength properties at a high melting point

Though simple to describe, these performance properties are inherently contradictory and difficult to engineer into a suitable material. To be efficacious, an electrode material must display no deformation at high temperatures; excellent thermal conduction; sufficiently low resistivity; and minimal reactivity, to prevent chemical alloying with the workpiece. It must also be available at a competitive cost.

In addition to material properties, electrode design—and particularly, tip design—should be carefully considered. The goal is to ensure a constant contact area between the tip surface and the workpiece, regardless of the electrode-to-part position. This contact helps to reduce electrode tip sticking and maximizes overall electrode life. Successfully achieving this involves three unique design considerations:

1. Materials cannot disintegrate during use and therefore reduce the contact patch.

2. Top and bottom electrodes must maintain their respective positions, as any misalignment or deflection will radically reduce the contact surface area.

3. Reduce the margin of error. This is commonly achieved by making the electrode tip area larger than the contact tip-to-part weld area so that the waste weld heat is dissipated, enabling the electrode to operate at a lower average temperature.

THE CONCLUSION

Though resistance spot welding is a mature process in which many of the challenges have already been uncovered, proper electrode material selection remains critical to successful process automation. Subtle process-driven interactions between the electrode and workpiece material can cause difficult problems, including imperfect or weak welds, tip sticking or alloying with the workpiece, or even electrode tips detaching from the shank.

However, given the right knowledge base regarding workpiece materials and the elemental and mechanical properties of electrode materials, selecting the right resistance spot welding electrode can help get production lines up and running efficiently, and keep them that way.

OUR COPPER TUNGSTEN RESISTANCE WELDING ELECTRODES



ABOUT

METAL CUTTING CORPORATION

Metal Cutting Corporation manufactures burr-free, tight tolerance parts from all metals. We provide the precision required by medical devices, automotives, electronics, biotechnology, semiconductors, aerospace, fiber optics, electrical, and many other diverse industries.

We are specialists with over 50 years of experience cutting, grinding, lapping, polishing, and machining metal parts. Additionally, Metal Cutting now offers specialty refractory metal electrodes.

Our electrode materials expertise is in tungsten, molybdenum, and their alloys, including copper tungsten and silver tungsten as well as carbide compositions and heavy metal electrodes. Our electrodes are used in high-speed, large volume automated resistance spot welding manufacturing environments and are also excellent for die sinker EDM.

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