Dissimilar Metals

Weld Tech News

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WELD TECH NEWS is a newsletter for welders working primarily in maintenance and repair. Each issue contains useful information on materials (cast irons, steels, aluminum, copper alloys, etc.), welding products and welding techniques. By collecting each issue, the reader will soon have a handy reference manual covering all aspects of welding, brazing and soldering for maintenance repair.

DISSIMILAR METALS

Welders involved in repair and maintenance situations as well as welders in production welding can be faced with applications requiring the joining of dissimilar metals. This would be the joining of metals or alloys of substantially different compositions such as carbon steel to stainless. The ease with which this is done can range from easy to impossible. Depending on the types of alloys to be joined the welding process used can be of critical importance. The common welding processes of soldering, brazing, stick electrode (SMAW), wire feed (GMAW and FCAW) and TIG (GTAW) all have their place in joining dissimilar metals. The physical properties of the base metals to be joined are a major factor in determining whether particular metals can be joined and the appropriate welding process to use.

PHYSICAL PROPERTIES

Melting point: The temperature at which a pure metal, compound or eutectic changes from a solid to a liquid; the temperature at which the solid and liquid are in equilibrium. (The Welding Encyclopedia, 18th Edition)

Aluminum and carbon steel melt at different points, aluminum commonly at 1220° F and mild steel at 2650° F. If we were to try to use a high heat welding process such as TIG welding to join these metals it would require the melting of both base metals. The aluminum would be a molten puddle well before we melt the steel. These metals can be joined but we would use a solder type alloy, one reason being that it works below the melting temperature of both metals. Welding dissimilar metals becomes more difficult the greater their difference in melting points.

Significant differences in melting temperature between a weld metal used to join base metals of different compositions can create stresses caused by the metal with the higher melting point. "Buttering" a layer or two of a filler metal with an intermediate melting temperature on the surface of the base metal with the higher melting point will help reduce the temperature differential.
Thermal conductivity: The property of a material to allow the passage of heat. The three mechanisms of thermal conductivity by which heat can be transmitted from a heat source to a material that are significant to welding are conduction, convection and radiation. Conduction is most often the mechanism involved in a weldment. (The Welding Encyclopedia, 18th Edition)

Metals conduct heat better than nonmetals and different metals can vary greatly in their heat conductivity. Aluminum conducts heat three to five times faster than carbon steel and copper is even a better heat conductor at about six times that of steel. The opposite is true of 300 series stainless steels since they have about 1/3 the thermal conductivity of steel, which means these stainless types generally require less heat to weld. On the other hand metals with high heat conductivity, even though they may have low melting temperatures, would require higher heat to weld them because the heat is dissipated so rapidly. Thus welding a thick piece of copper alloy to a carbon steel would be difficult with a low heat source such as oxy-acetylene. One of the electric arc welding processes would be best for such an application. Thin pieces of these different metals would be less difficult to join with oxy-acetylene since their mass would be so little, they would both heat relatively quickly.
In welding together the different parts of a workpiece the welder always needs to take into consideration how the different parts of the piece will expand and contract due to their differences in temperature. This becomes more complex when different metals are welded with their different rates of expansion and contraction as well as their different rates of heat conductivity.

Thermal expansion – The increase in the dimensions of metals caused by heat. When metals are heated they expand in every direction. The expansion in length is linear expansion; the increase in volume is cubical expansion. Conversely, a decrease in temperature causes the metal to contract. (The Welding Encyclopedia, 18th edition)
Some metals, such as steel, are ductile and will distort, warp or buckle from heat expansion. Metals such as cast iron, copper and aluminum are not very ductile and expansion from heat can cause internal strains which can lead to fractures within the metal. Such metals should not be restrained when welded. Welding steel to cast iron, for example, would require a weld deposit with some ductility or elongation to allow the steel to expand and contract under the heat of welding versus the less forgiving cast iron. Thought also must be given in this situation as to where the welds should be so as not to create stresses within the cast iron. A nice square piece of steel welded onto a piece of cast iron may look good, but those parallel welds could be creating internal stresses on the underlying cast iron.

Dilution: The change in chemical composition of a welding filler metal caused by the admixture of the base metal or previous weld metal in the weld bead. It is measured by the percentage of base metal or previous weld metal in the weld bead. (The Welding Encyclopedia, 18th edition)
When arc welding, it must always be remembered that the weld is not just made up of the melted filler metal but also the melted base metal. It combines with the filler metal in the heat of the arc to give you a weld. This is an extra consideration in welding dissimilar metals because melting some metals together simply may not work. Such a situation may require brazing or soldering so as not to actually melt the base metals. Some arc welds of dissimilar metals are subject to failure because of dilution of the weld metal by the base metal. The process would work with the appropriate filler metal. If we use a stainless filler to arc weld a piece of stainless to a piece of copper alloy the weld could be subject to cracking because the copper base metal diluted the stainless weld. Too much copper in a stainless weld can cause the weld to crack. We can, however, arc weld these metals together using a copper alloy filler metal because it can tolerate dilution from the stainless. "Buttering" the joint area with a buffer filler metal can also be a solution to the base metal dilution problem. The filler metal then welds to the buffer metal minimizing the dilution of the weld deposit by the base metal.

**Buttering**: A surfacing variation that deposits surfacing metal on one or more surfaces to provide metallurgically compatible weld metal for the subsequent completion of the weld. (The Welding Encyclopedia, 18th Edition)

We now have some basic physical properties to consider when looking at welding dissimilar metals. These factors will help to determine which welding process to consider for an application and what would be appropriate alloys to use as well as procedures.

### Physical Properties of Various Metals vs Carbon Steel

<table>
<thead>
<tr>
<th>Relative Property</th>
<th>Carbon Steel</th>
<th>Copper</th>
<th>Aluminum</th>
<th>Austenitic Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean coefficient of Thermal expansion</td>
<td>1.0</td>
<td>1.5</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>1.0</td>
<td>5.9</td>
<td>3.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Heat capacity</td>
<td>1.0</td>
<td>0.8</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Density</td>
<td>1.0</td>
<td>1.1</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Melting Temperature</td>
<td>1.0</td>
<td>0.7</td>
<td>0.4</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**APPLICATIONS**

Some typical dissimilar welding applications:

STEEL to STAINLESS: Thin, small pieces can be silver brazed or soldered. Larger pieces can be arc welded with stick, TIG or wire feed. A chrome-nickel alloy is used with high elongation being desirable to aid in the weld being able to "give" with the different rates of thermal conductivity of
the metals. A "straight" stainless filler such as a 308 type, when used to weld steel to stainless, can be prone to cracking due to dilution of the weld deposit.

STEEL to CAST IRON: Typically arc welded, usually with nickel type stick rod but small pieces can be brazed. Wire feed can be problematic due to the higher arc heat usually involved. High nickel electrodes with good elongation help minimize cracking as well as appropriate preheat techniques. Vee joints and use buttering procedure on larger pieces. Steel patches should not be square but odd shaped to minimize creation of stress lines in the cast base metal.

STEEL to COPPER ALLOYS: Thin, smaller pieces can be silver brazed or soldered. Arc weld with stick, TIG or GMAW for larger pieces. TIG works especially well for heat control on the very different thermal conductivity of the metals. Silicon-bronze and aluminum-bronze filler metals provide good welds but not as strong as the steel can be. Clean base metal and preheat thick pieces.

ALUMINUM to OTHER METALS: Thin, smaller pieces can be soldered with very low heat. Minimal tensile strength. Aluminum has low melting temperature and oxides which do not make normal arc welding feasible.

STEEL to CARBIDES: Carbide tool bits for cutting steel on lathes and mills. Silver brazing will go to both metals with minimal heat. Buttering flat surfaces together requires "tinning" both pieces first and then joining with reheat.

COPPER to STAINLESS: Thinner pieces can be silver brazed or soldered. Can be arc welded with bronze type stick electrodes though GMAW and especially TIG welding gives the best results. Silicon-bronze and aluminum-bronze filler metals can handle dilution from the base metal. The particular copper alloy may determine which filler metal. Clean base metal is important and applications with thick copper may require preheat.

WELDING ALLOYS FOR DISSIMILAR METALS

Brutus-AAA (127,000 p.s.i.) and Brutus-A (125,000 p.s.i.) electrodes are chrome-nickel alloys most especially engineered for welding dissimilar steels of many different combinations. Typical applications would be carbon steel to stainless, cast steel to steel, manganese to carbon steel, and hardened steels such as bolts, drill steel and tool steels to carbon steels. With an elongation of 35%, these electrodes provide welds with superior ductility to cope with stresses in the weldment caused by differences in expansion and contraction of different steels. Their metallurgy is advantageous in dealing with dilution and provides a good ferrite level providing good crack resistance and good strength. For wire feed welding use Brutus-MIG.
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Apollo-B (105,000 p.s.i.) is a stainless alloy that can be used to join dissimilar metals as well as being an excellent build-up electrode. It is most suitable for applications involving joining manganese steels and manganese to carbon steels. It provides welds with 37% elongation and deposits are machinable but will work harden under impact up to 45 RC.

Jupiter-AAA (70,000 p.s.i.) and Jupiter-A (79,000 p.s.i.) are nickel-iron electrodes that are superior for welding dissimilar combinations of cast iron to carbon steel. They exhibit high elongation and superior strength for such applications. Ideal for applying steel “patches” to cast iron. These electrodes would also be suitable for joining cast iron to stainless. They handle high contamination in the base metals, minimizing porosity.

Jupiter-BBB (65,000 p.s.i.) and Jupiter-B (64,000 p.s.i.) are very high nickel electrodes that will join cast iron to carbon steel and provide welds with good machinability. Deposits are resistant to cracking with good puddle fluidity. These electrodes run excellent out of position with superior weld puddle control.

Jupiter-TIG-B (60,000 p.s.i.) is for TIG welding cast iron and cast iron to steel. Ideal for thinner metals and critical, machinable welds the high nickel deposits provide precise weld puddle and heat control. This can often be the solution to cast iron weld problems.

Venus-A (50,000 p.s.i.) and Venus-B (63,000 p.s.i.) are bronze alloy electrodes with many dissimilar metal joining applications. Suitable for welding copper alloys such as brass and bronze to steel because of their low melting temperature. Also suitable for copper alloys to stainless. For wire feed welding use Venus-MIG.

Venus-C (106,000 p.s.i.) is an aluminum bronze electrode that has great versatility in dissimilar metal welding. The alloying of this electrode can solve many problems in the joining of bronze to steel, copper to steel, cast iron to steel, bronze to cast iron and stainless to copper alloys. Deposits are machinable and corrosion resistant.

Venus-TIG (60,000 p.s.i.) allows the heat control and precision deposits of the TIG process to be used to join copper alloys to carbon steels, cast iron and to stainless. It can also be used on galvanized steels without burning off the zinc coating. Deposits are machinable and corrosion resistant.

Venus-TIG-C (106,000 p.s.i.) is a highly alloyed aluminum bronze TIG filler with great versatility in joining copper alloys as well as dissimilar combinations. The addition of nickel and manganese make it the ideal filler and process for joining bronzes and other copper alloys to ferrous metals, stainless steels and cast irons. Deposits are corrosion resistant and machinable.

Gemini-G (flux coated) and Gemini-GB (bare) (88,000 p.s.i.) are silver brazing alloys whose very high silver content and low melting temperature 1090° F (587° C) make them an ideal choice for joining thinner pieces of dissimilar metals. They will join all metals except white metals
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and will provide an excellent color match when used on stainless. Common applications would include copper to stainless, brasses and bronze to stainless, stainless to carbon steels and carbide tool bits. Excellent wetting action. Use with Gemini Flux. Not for white metals.

Apollo-G (flux coated) and Apollo-GB (bare) (88,000 p.s.i.) have a high silver content and a melting range that allows for thin flow as well as bridging gaps in poorly fit up joints. They will join all metals but is especially suited for joining dissimilar metals in such applications as hydraulic repairs, radiators and tubing. Use with Gemini Flux. Not for white metals.

Venus-G (52,000 p.s.i.) is a bare silver brazing alloy suitable for joining copper and copper alloys such as brass and bronze to each other. It has excellent wetting action and thin flow with a low melting temperature 1175° F (635° C).

Gemini-S, Gemini-SA (acid flux core), Gemini-SR (rosin flux core) and Gemini-SSP (paste-acid flux) are silver solders with very low melting temperatures 420° F (215° C) and high strength (16,000 p.s.i.). Lead and cadmium free, they will join any metal except white metals.

Neptune-SS is a very low temp 320° F (180° C) solder that will join aluminum to other metals such as stainless and copper. Use with Neptune Solder Flux.

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