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Welcome to the forth issue of ***Tech Talk***. This newsletter covers a range of topics on various welding products, applications, metallurgy, techniques, and economics. Previous issues are archived at www.unibraze.com. Submit any questions or comments to leroy@unibraze.com or call 1-877-233-1375.

In this issue, we will look at the filler metals that fall under the AWS specification 5.3-92 "Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding" but first we will look at some general information on aluminum.

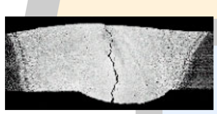
Aluminum Physical Properties

How does aluminum compare to steel?
1) Aluminum is three times lighter than steel and yet can offer high strength when alloyed with the right elements.
2) Aluminum can conduct electricity six times better than steel and nearly 30 times better than stainless steel.
3) Aluminum provides excellent corrosion resistance.
4) Aluminum is easy to cut and form.
5) Aluminum is nontoxic for food applications.
6) Aluminum is non-magnetic therefore arc blow is not a problem during welding.
7) Aluminum has a thermal conductivity rate five times higher than steel. The high thermal conductivity creates a great heat sink which can create insufficient weld fusion on parts over 4 mm and weld burn through issues on parts less than 3 mm.
8) Aluminum has a low melting point of 1,200 degrees F; this is more than half that of steel.

Aluminum Porosity and Hydrogen

Aluminum is one of the metals most susceptible to porosity. Hydrogen dissolved in the liquid weld metal will try to escape as the aluminum solidifies, and trapped hydrogen will result in weld porosity which is often extensive.
The main cause of porosity in aluminum welds is the absorption of hydrogen in the weld pool which forms gas pores in the solidifying weld metal. The most common sources of hydrogen are hydrocarbons and moisture from contaminants on the aluminum base metal and on the filler wire surface.

Weld Cracking



Hydrogen cracking, which is common with carbon steels, will not occur with aluminum. The primary cause for aluminum cracks is hot cracking, or solidification cracking. **Aluminum hot cracking** is a result of high thermal stresses, weld shrinkage, and metallurgical reactions while the aluminum weld metal solidifies. These **Aluminum Solidification cracks** can happen due to thermal expansion and contraction during the welding process, thus generating high stresses, which can sometimes tear the weld apart.

Common causes of solidification cracks

1) Incorrect choice of aluminum weld consumable.
2) Concave welds, undersize welds, and welds with insufficient weld throat. (The weld throat depth must be sufficient to compensate for the weld contraction stresses).
3) Weld joints too rigid.
4) Poor weld geometry.
5) Poor weld joint design: Weld restraint and weld stresses can be reduced by focusing on the weld edge prep, and/or the weld sequence.
6) Excess weld heat: Watch weld pass sequence and on multi-pass welds consider interpass temperature control.

Solidification cracking is reduced with the selection of crack-resistant filler metal like the 4xxx and 5xxx filler metal. Be wary when choosing the filler metal to specifically reduce weld cracking, as the weld metal may provide lower strength than the parent metal and will not respond to heat treatment if applied.

Aluminum Liquation Cracking

In contrast to hot cracking which occurs in the weld, aluminum liquation cracking will occur in the heat affected zone (HAZ). With liquation cracking, low melting point films are formed at the grain boundaries. These films (liquid elements) can not withstand the contraction stresses during the weld metal solidification. Heat treatable alloys, like the 6xxx and 7xxx series, are sensitive to liquation cracking. To reduce the potential for liquation cracking, consider a filer metal with a lower melt temperature than the parent metal. With alloy 6061 - 6082, liquation cracking can occur in the partially melted zone when a weld with good dilution is made with

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5356 or similar filler metal is utilized. In contrast when welding the same alloys with 4043 liquation cracking should not occur.

Aluminum Oxides

Aluminum will also combine with oxygen to form an aluminum oxide layer. This layer will form instantly as the aluminum surface is ground or machined. The aluminum oxide layer, while very thin, can also be extremely porous. The oxide layer will readily trap moisture, oil, grease and other materials adding to the potential for hydrogen pickup. The aluminum oxide layer provides excellent corrosion resistance; however, this layer must be removed before welding as it prevents fusion due to its high melting point (3700 degrees F). Mechanical cleaning, wire brushing, solvents and chemical etching are used for the oxide removal.

Aluminum Descriptions

1XXX: Minimum 99% aluminum. This very low strength series is considered non-heat treatable and is used primarily for bus bars and some pipe and chemical tanks. This alloy provides superior corrosion resistance. Alloys with purity levels greater than 99.5% are used for electrical conductors (for example alloy 1350). 1XXX series are easily welded with 1100 and 4043 alloys.

2XXX: Alum-Copper provide approx. 2 to 6% Cu with small amounts of other elements. The Cu increases strength and enables precipitation hardening. The 2XXX series is mainly used in the aerospace industry. Most of the 2XXX alloys have poor weldability because of their sensitivity to hot cracking. These alloys are generally welded with 4043 or 4145 series filler electrodes and have low melting points which help reduce the probability of hot cracking. Exceptions to this are alloys 2014, 2219 and 2519, which are readily welded with 2319 filler wires. Hot cracking sensitivity in these Al-Cu alloys increases as copper is added up to 3% and decreases when the copper is above 4.5%. Be wary of Alloy 2024 as it is crack sensitive.

3XXX: Alum-Manganese when added to aluminum produces a moderate strength, non-heat treatable series typically used for radiators, cooking pans, air conditioning components, beverage containers and storage equipment. The 3XXX series is improved through strain hardening which provides improved corrosion properties and improved ductility. Typically welded with 4043 or 5356 electrode, the 3XXX series is excellent for welding and not prone to hot cracking. The moderate strength of this series prevent these alloys from being utilized in specific fabrication or structural applications.

4XXX: Alum-Silicon reduces melting temperature and improves fluidity. The most common use is as a welding filler material. The 4xxx-series alloys have limited industrial application in wrought form. If magnesium is added, it produces a precipitation hardening heat treatable alloy. The 4XXX series has good weldability and can be a non-heat-treatable or heat treatable alloy. It is used for castings and weld wires. The 4xxx wires are more difficult to feed than the 5xxx series.

5XXX: Alum-Magnesium increases mechanical properties through solid solution strengthening and improves strain hardening potential. These alloys have excellent weldability with a minimal loss of strength. The 5 XXX series has lower tendency for hot cracking. The 5XXX series provide the highest strength of the non heat-treatable aluminum alloys. These alloys are used for cryogenic vessels, chemical storage tanks, auto parts, pressure vessels at elevated temperatures, etc. Because of their corrosion resistance they can also be used for structural applications such as railway cars, trailers, dump trucks and bridges. 5xxx looses ductility when welded with 4xxx series fillers due to formation of Mg2Si.

5xxx Crack Sensitivity: The 5xxx, typically while welding with or without filler metal, have low crack sensitivity. Usually the filler metal will have a little more Mg than the base metals being welded. Be wary of 5052, especially if TIG welding without a filler metal. Use a high Mg filler like 5356 for the 5052 alloy. All aluminum concave fillet welds and concave craters are sensitive to hot cracks.

6XXX: Alum-Magnesium & Silicon (magnesium-silicides) combine to serve as alloying elements for this medium-strength heat-treatable series. 6XXX are principally used in automotive, pipe, structural, railings and extruded parts. This series can be prone to hot cracking, but can be overcome by the correct choice of joint and filler metal and weld procedures that minimize weld heat input. This series can be welded with either 5XXX or 4XXX series. Adequate dilution of the base alloys with selected filler alloy is essential. 4043 electrode is the most common filler metal for this series. Be wary of

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liquation cracking in the HAZ when using specific 5xxx alloys. See Liquation cracking above notes.

6xxx Crack Sensitivity: As many of the 6xxx alloys have 1.0% magnesium silicide, these alloys are crack sensitive. Avoid welding without filler metal, and do not use 6xxx material as the filler metal. Using 4xxx or 5xxx filler metals reduces crack sensitivity as long as sufficient weld metal is added and good weld dilution occurs. Avoid weld joints in which minimal weld dilution occurs; a “v” prep is superior to a square groove. All 6xxx aluminum applications that have concave welds and concave craters are sensitive to hot cracks.

7XXX: Alum-Zinc, when added to aluminum with magnesium and copper, permits precipitation hardening and produces the highest strength heat-treatable aluminum alloy. These alloys are primarily used in the aircraft industry, armored vehicles and bike frames. The weldability of the 7XXX series is compromised in higher copper grades, as many of these grades are crack sensitive (due to wide melting ranges and low solidus melting temperatures) and susceptible to stress corrosion cracking. Grades 7005 and 7039 are weldable with 5XXX fillers.

7xxx Crack Sensitivity: The 7xxx Al-Zn-Mg alloys (typically welded with 5356 avoid 4043) resist hot cracking better than the 7xxx Al-Zn-Mg-Cu alloys.

8XXX: Other elements that are alloyed with aluminum (i.e. lithium) all fall under this series. Most of these alloys are not commonly welded, though they offer very good rigidity and are principally used in the aerospace industry. Filler metal selection for these heat-treatable alloys include the 4XXX series.

Aluminum Welding

The reason why aluminum is specified for so many jobs is that their alloys provide unique physical properties.

Weight: Aluminum is three times lighter than steel and yet can provide higher strength when alloyed with specific elements.

Conductivity: Aluminum can conduct electricity six times better than steel. The high electrical conductivity makes the effect of electrical wire stick-out in MIG welding less of a concern than when compared to steel MIG welding. With aluminum being more sluggish and less fluid, it can be welded in all positions with spray, and pulsed with relative ease. In contrast to steel, the high conductivity of aluminum acts as a heat sink making weld fusion and weld penetration more difficult to achieve.

Non Magnetic: Since it’s non-magnetic, arc blow is not a problem during aluminum welding.

Thermal Conductivity: Aluminum has a thermal conductivity rate that is five times higher than steel.

Aluminum alloys difficult to weld

Alloys that may be sensitive to hot cracking are found in the 2xxx series, alum-copper and in the 7xxx series alum-zinc.

With the 2xxx series, hot cracking sensitivity increases with Cu < 3% and decreases with Cu > 4.5%. Avoid weld practices that promote high heat input as grain boundary segregation cracking potential can occur.
7xxx alloys that contain Al-Zn-Mg, such as 7005, resist hot cracking. They have better mechanical weld properties than Al-Zn-Mg-Cu alloys like 7075 that contain small amounts of Mg and Cu. This extends the coherence range, increasing crack sensitivity. Zirconium is added to refine grain size and reduce crack potential. Electrode 5356 is often recommended for this group as the magnesium helps prevent cracking. The 4043 electrode would provide excess Si, promoting brittle Mg2Si particles in the welds.

Be careful when welding dissimilar aluminum alloys, as extending the coherence range increases crack sensitivity. When welding alloys that do have good weldability, like 5xxx alloy to a 2xxx base alloy, or a 2xxx filler on a 5xxx alloy and vice a versa, you can end up with high Mg and Cu. This can increase the coherence range, again increasing the crack sensitivity.

Electrodes

AWS A5.3-92 lists three major classifications for Aluminum and Aluminum Alloy Electrodes. They are E1100, E3003, and E4043. Of these, E1100 and E4043 are the most common electrodes used.

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Classification Details:

Alloy 1100 is a pure aluminum (99% or greater) and is strain hardenable. It is highly resistant to chemical attack and weathering, but would not be used where strength is a prime consideration. Rather, the emphasis would be on those applications where extremely high corrosion resistance, formability and/or electrical conductivity are required. Alloy 1100 wires and rods are generally recommended for welding 1100 and 3003 aluminum sheets, plates and shapes.

Alloy 4043 is one of the oldest and most widely used welding and brazing alloys. E4043 can be classed as a general purpose type filler alloy. The silicon additions result in improved fluidity (wetting action) making this alloy the preferred choice of welders. The alloy is less sensitive to weld cracking and produces a brighter, almost smut- free weld.

In our next issue, we will discuss AWS A5.4 “Stainless Steel Electrodes for Shielded Metal Arc Welding” (SMAW).