Aluminum Issues

Weld Tech News

VOL 1. NO. 3

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, welding techniques and safety. By collecting each issue, the reader will soon have a handy reference manual covering all aspects of welding, brazing and soldering for maintenance and repair.

ALUMINUM
Its Properties and Peculiarities

Aluminum is the most abundant metal in the earth’s crust, being about 8% of the crust’s weight, compared with iron at 5%. It occurs throughout the earth’s surface, but is mined mainly in the tropics, where temperature and rainfall over millions of years have concentrated the aluminum oxide deposits into economically mineable bauxite ore.

Aluminum and oxygen combine so easily and so tightly that pure metallic aluminum could not be separated from the oxide until 1845. The cost was $545 per pound in 1852, which dropped to about $10 in 1885. New electrolytic processes for producing aluminum, developed in 1886, caused the price to drop to 33¢ per pound by 1900, but by 1981 inflation (and especially the high cost of energy) had pushed the price back up to about 76¢ per pound or about the same current price per pound as copper. Because aluminum is so much lighter than copper, however, its cost per cubic foot is only about 30% of the cost of copper.

Properties of Aluminum

Aluminum's high thermal and electrical conductivity, together with its cost advantages, make a natural substitute for copper in many electrical applications and in heat transfer devices, such as radiators. These uses were limited in the past, because many applications required joining aluminum to other metals. In older joining methods, a brittle intermetallic alloy was formed in the joint, causing early joint failure. Newer materials and processes allow us to join aluminum to other metals without the intermediate brittle alloy.

The thin, tough oxide coating, which forms immediately when aluminum is exposed to air, protects the metal below from further corrosion. This allows aluminum to be used, in most cases, without further surface protection.

However, this same oxide coating increases the electrical surface contact resistance, which has caused aluminum to be outlawed for home wiring, where it once looked so promising. This oxide coating also
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makes aluminum difficult to solder, weld, or braze to itself or to other metals. Fortunately, we have been able to develop fluxes and methods for soldering, brazing and welding that get around this problem.

Aluminum is non-magnetic, non-toxic, attractive in appearance and reflective to radiant energy, such as light, heat and radio waves. It has high workability and is easy to shape by extruding, forging, rolling, drawing, bending and machining. It also has good cryogenic properties; that is, it does not become brittle at low temperatures.

Aluminum has a high strength to weight ratio. Although the tensile strength of pure aluminum is only 6500 p.s.i. alloying and heat treating can increase this to almost 100,000 p.s.i! The combinations of strength and lightness have always made aluminum important in the aircraft industry. The current need for lighter vehicles and greater fuel economy has led to an increasing use of aluminum automobile parts.

Aluminum Alloys

Aluminum is produced in casting alloys and wrought alloys. Casting alloys generally have much less ductility than wrought alloys of similar composition and are generally more difficult to weld.

Wrought alloys are used to produce shapes by extrusion, rolling, forging or drawing. They do not need to be as fluid in pouring as the cast alloys, but they are more ductile.

Wrought alloys are classified under a four-digit numbering system. The first digit in each number indicates the major alloying metals as shown below:

- 1000 Series - Commercially pure aluminum (minimum 99%). Excellent corrosion resistance and electrical conductivity, but low strength. Examples include alloy 1060 (chemical equipment), 1100 (sheet metal) and 1350 (electrical wires). Not heat-treatable. Easy to weld, braze and solder.
- 2000 Series - Up to 5 1/2% copper increases strength, but reduces corrosion resistance. Heat-treatable to further increase tensile strength up to 70,000 p.s.i. Used for truck-trailer panels and aircraft structures. Poor weldability.
- 3000 Series - Addition is about 1.2% manganese increases strength over 1000 series, but 3000 alloys still have good workability. Not heat treatable. Widespread use for cooking vessels, heat exchangers, furniture, roofing, siding and highway signs. Good for welding, brazing and soldering.
- 4000 Series - Up to 12% silicon. Used in welding filler metal, forgings and some anodized parts.
- 5000 Series - Magnesium (0.3-5.0%) gives moderate to high strength and good corrosion resistance in marine atmospheres. Used for architectural trim, ships and boats, cryogenic tanks and crane parts. Not heat-treatable. Good weldability, but some 5000 alloys, such as 5052 and 5083, are hard to braze or solder.
- 6000 Series – These aluminum/magnesium/silicon alloys have good formability, corrosion resistance and machinability. Best known alloys are 6061 and 6063, used for architectural installations, transportation equipment, bridge railings and other welded constructions. Heat-treatable. Good for welding, brazing and soldering.
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- 7000 Series - Addition of zinc (3-8%) plus magnesium, when heat treated and aged, gives alloys with very high strength (up to 83,000 p.s.i.). Used primarily for aircraft structures and other applications needing maximum strength-to-weight ratio. Hard to weld, braze or solder.
- 8000 Series - This series includes all other wrought alloys not in the 1000-7000 series. Alloying metals include beryllium, bismuth, boron, iron, lead, nickel, sodium, tin, titanium and zirconium.

Casting alloys have a separate, four-digit numbering system. Examples include:

- 319.0, an aluminum/silicon/copper alloy used for automobile cylinder heads.
- 380.0, an aluminum/silicon/copper/iron alloy used in die casting lawn mower housings and gear cases.
- 443.0, an aluminum/silicon alloy, widely used for sand and permanent mold castings of cooking utensils, food handling equipment and marine fittings; and
- 713.0, an aluminum/zinc alloy used in cast aluminum furniture and other high strength applications.

Tempering

All pure metals and many alloys can only be strengthened or hardened by strain hardening or cold working resulting from rolling, bending, forging or peening. Strain hardened metals will soften when welded or heated by other means.

Many alloys, perhaps half of those that the welder encounters, can also be strengthened, hardened, or otherwise improved by the application of heat and aging.

These are called heat-treatable alloys. Both casting and wrought alloys can be either heat-treatable or not heat-treatable.

The wrought or cast alloy designation is often followed by a dash and a letter showing the temper designation, such as "F" (as fabricated), "O" (annealed), "W" (solution heat treated), "H" (strain hardened), or "T" (heat treated).

Numbers following an "H" or "T" indicate the type and degree of strain hardening or heat treatment.

Shown below are several typical examples of the increase in strength, and decrease in ductility, caused by strain hardening or heat treating:
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<table>
<thead>
<tr>
<th>Alloy and Temper</th>
<th>Tensile Strength (PSI)</th>
<th>Yield Strength (PSI)</th>
<th>Ductility (% in 2 inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024-0</td>
<td>27,000</td>
<td>11,000</td>
<td>22</td>
</tr>
<tr>
<td>2024-T4</td>
<td>68,000</td>
<td>47,000</td>
<td>19</td>
</tr>
<tr>
<td>3004-0</td>
<td>26,000</td>
<td>10,000</td>
<td>25</td>
</tr>
<tr>
<td>3004-H32</td>
<td>31,000</td>
<td>25,000</td>
<td>17</td>
</tr>
<tr>
<td>3004-H38</td>
<td>41,000</td>
<td>36,000</td>
<td>6</td>
</tr>
</tbody>
</table>

“Alcad” sheets or strips are sandwich constructions formed by bonding a thicker inner layer of a tempered alloy with thinner outer layers of a different, more corrosion-resistant alloy. Usually the outer coating can be soldered or brazed easily, but welding heat can change the properties of the inner layer.

The Welding Shop

ALUMINUM - HOW TO BRAZE, WELD AND SOLDER IT

Many maintenance and repair welders have trouble joining aluminum, because it requires different techniques from those used with steel. Rockmount engineers have, therefore, developed a group of specialized products and techniques, as described below, to insure trouble-free joining of aluminum.

Joining aluminum is different from joining steel in several ways:

- Aluminum alloys melt at a much lower temperature, typically 890°-1215°F (477°-657°C).
- Aluminum does not change color as it approaches melting temperature. When using a gas torch, the welder can easily overheat the aluminum base metal.
- The oxide coating on aluminum must be removed, chemically or mechanically, to insure a good bond between base metal and filler metal. Since the oxide melts at a temperature 3-4 times higher than the metallic aluminum, the oxide cannot be simply “burned off” by the welding heat.
- Aluminum expands more than steel when heated. Steel jigs and fixtures designed to hold aluminum parts for welding, brazing and soldering must allow for heat expansion to prevent buckling.

Almost all wrought aluminum alloys can be welded, brazed, or soldered, some better than others. In general, the higher the potential tensile strength of an alloy, the more susceptible that alloy is to cracking during welding, so that more care should be taken to avoid restraint in joint design and fixturing for welding. Heat treatable alloys that have been treated to their maximum strength are also more crack sensitive during welding than if the same alloy is welded in the annealed condition.
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Occasionally, aluminum is “anodized” by chemical treatment to build up a heavy oxide coating. This oxide coating has superior corrosion and wears resistance.

Anodizing is frequently done on finished welded assemblies, but repair welding cannot be done without first removing the anodized layer. All Rockmount aluminum alloys can be anodized after welding.

As discussed on the previous page, many aluminum alloys have been tempered by strain hardening or by heat treating and aging. The heating, melting, and cooling cycle in repair welding will seldom duplicate this tempering process exactly, so that the weldment will usually end up having somewhat different properties than the base metal. Even if the heat treatable alloy was in an annealed condition at the time of welding, the welding heat input may harden the base metal in the heat affected zone next to the weld and change its properties.

In most repair welding, some reduction in strength in the weld is not a problem. Generally the weld design can provide adequate strength for the purpose intended. The welder's problem is to insure that the weld area is completely fused, without porosity, cracks, or brittleness.

Aluminum's excellent heat conductivity may cause the welding zone to cool too rapidly, resulting in high stresses, distortion and cracking. To slow down the cooling rate in heavy sections, it is a good idea to preheat the base metal to 300-500°F. For TIG or MIG welding, this is less important.

Arc Welding

*Neptune-A* is a flux-coated stick electrode for welding with D.C. reverse polarity (electrode positive). The flux coating provides a gas shield around the arc and helps remove the aluminum oxide coating, converting it to an easily-removed slag.

*Neptune-A* contains a special aluminum alloy that provides strong welds (up to 35,000 p.s.i.) in joining almost all aluminum base metal alloys. It is typically used wherever D.C. welding equipment is available.

For best results, the joint area should be cleaned mechanically and degreased. A stainless steel brush is helpful, since there is no risk of leaving rust inclusions (from an ordinary wire brush) or grit inclusions (from sandpaper or sand blasting).

Because of the concentrated arc heat, penetration is excellent and cracking is minimized. Joints can be beveled, although it is possible to weld up to 1/4” inch thick with plain square edges. Slag deposits should be cleaned between passes. For best results, unused *Neptune-A* should be properly stored where it will be kept clean and dry.

*Neptune-TIG* is a bare aluminum alloy used with the tungsten-inert-gas (TIG) process. In TIG welding, the filler metal is fed by hand into an electric arc generated between a tungsten electrode and the work piece. The force of the arc breaks up the oxide coating and a flow of inert gas -- either argon or helium -- prevents air from reaching the weld area and forming new oxide.
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Either argon or helium, or a mixture, can be used for the inert gas shield. However, argon is preferred for manual welding because it gives a smoother arc action, is cheaper and easier starting, and gives better cleaning action on aluminum.

TIG welding is an excellent way to produce clean, uniform aluminum welds, when the proper power source is available. Although D.C. can be used for TIG, the most satisfactory power source is A.C. with a superimposed high-frequency voltage, since A.C. provides the best “arc cleaning” action on the oxide.

Although pure tungsten electrodes or thoriated tungsten can be used for aluminum TIG, most welders find that zirconiated tungsten works best. The electrode should have a rounded end and the arc length should be kept short.

Like Neptune-A, the Neptune-TIG alloy is specially designed for compatibility and good results with a wide variety of aluminum base metal alloys. This is particularly important for the repair welder, who cannot always determine the exact alloy of the piece to be repaired.

Where conditions permit, Neptune-TIG is the preferred filler metal for TIG welding aluminum. However, when complete precleaning of the base metal is difficult, or where high frequency arc stabilization is not available, Neptune-GCF will provide excellent results in TIG welding. Neptune-GCF has a flux core which assists the cleaning action.

TIG welding is generally used on thin sections, 1/8” or less, in applications such as furniture parts and architectural trim, where appearance and strength are important.

Metal inert gas (MIG) welding is similar to TIG. However, instead of having a non-consumable tungsten electrode and a hand-fed filler metal wire, the MIG process uses a continuously-fed filler wire as the electrode. Shielding, as in TIG, is provided by a continuous flow of inert gas.

MIG welding provides very high deposition rates and excellent quality. It is generally suitable for production applications, where the higher equipment cost and longer set-up time can be justified. Rockmount can supply information on available Neptune MIG wires on request.

Brazing

Using suitable filler metals, oxy-fuel torches will make excellent joints in many aluminum alloys where fusion welding (melting of base metal) is difficult or not recommended. It is applicable to almost all sheet (wrought) or cast aluminum alloys and will provide high joint strength and stand up in high temperature applications.

Brazing aluminum is similar to brazing other metals, with a few special precautions. A soft carburizing flame should be used to heat the piece quickly and evenly to brazing temperature. Since aluminum conducts heat very well, slow heating will greatly increase the size of the heat affected area and will
increase the total heat input required. Since aluminum does not show color changes when approaching its melting temperature, the welder must be careful not to overheat.

Proper jigging is important to allow the work piece to expand when heated and to support it. Although aluminum is very strong at room temperature, its strength near its melting point is very low. Unlike steel, aluminum brazing temperatures are quite close to the melting temperature of the base metal.

The flame should not be held on any portion of the assembly for more than a moment, but should be played over the work from side to side or in a circle. For maximum heat, the outer edge of the cone can be allowed to touch the work. Normally it is not brought any closer.

To bring parts of varying mass and surface area to the same temperature, the torch flame should be moved rapidly over light, thin sections and more slowly over heavier sections.

Joint temperatures can be judged by three methods. As the temperature increases, the flux will dry, turn white, and then melt and turn grey. As the brazing temperature is reached, the flux will become transparent and the subsurface aluminum will become shiny. Temperature indicating crayons, supplied by Rockmount, can be used to make a mark near the joint. When the crayon melts, the indicated temperature is reached.

The third method is to touch the filler metal to the work occasionally as the base metal is heated. When the filler tip melts, brazing temperature is reached.

When brazing temperature is reached, the torch should be withdrawn a bit to avoid overheating. Whether the torch flame is directed on filler metal or parent metal depends on the thickness of the parts brazed. If the parts are very thin, it may be desirable to direct most of the heat onto the filler wire. Otherwise, most or all of the heat should be directed onto the parts and clear of the filler.

The usual practice is to feed the filler wire or rod directly into one end of the joint, letting the molten filler find its own way down the length of the joint. If the joint is long, it may be necessary to supply the filler metal from several points successively. Supplying the metal from one point is better, however, as there is less chance of flux entrapment.

**Neptune-G** is a universal brazing filler metal for making joint strengths consistent with the base metal. It can be used on wrought or cast aluminum in thin flow joints or for buildup. **Neptune-G** is used with **Neptune Flux**, which comes as a powder for direct application or can be mixed with water to form a paste.

**Neptune-GCF**, the flux-cored version of **Neptune-G**, can also be used for brazing. **Neptune-GCF** requires no additional flux and is superior for building up missing sections.
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Soldering

Aluminum alloys may be readily soldered with good techniques and proper alloys. However, lead-tin solders, which are used on copper alloys and steels, are not satisfactory on aluminum.

Neptune-S is a very special filler metal which acts like solder, but is primarily used to build worn areas, salvage castings and fill holes where high strength is not required. It is self-fluxing, so that no separate flux is required. The low application temperature (670°F) prevents any melting of the base metal and should not change the temper properties of the part being repaired. It can easily be applied with an oxy-fuel torch.

Neptune-SS is a special low temperature solder (320°F) with excellent wetting characteristics, which can be used on all aluminum alloys, white metal and zinc die castings, and for joining aluminum to copper or steel alloys. It is used with Neptune Solder Flux. If heating with a torch, apply the heat indirectly, not on the flux. When the flux boils, apply the alloy.

For all brazing or soldering, it is important to remove all remaining flux, usually with hot water, after joining is complete.

Safety Tips for Welders

PROTECTING YOUR EYES

Welders, and people who work around welders, should know the basics of eye protection. Flying sparks, slag chips, or grinding abrasives present obvious eye hazards. If you are close enough to be in the range of these flying objects, wear safety glasses or other eye protection.

Ultraviolet radiation hazards are not so well understood. “Welder’s flash,” also known as “arc eye” or "snow blindness" resembles sunburn of the eyes. Like sunburn, it is mainly caused by overexposure to ultraviolet rays. The intense ultraviolet of a Welder’s arc can cause serious irritation or injury in less than a minute.

Welders can use goggles with tinted lenses in situations requiring up to a No. 6 lens. For heavier work, requiring a No. 8 or darker lens, a helmet or shield should be used to protect the welder's face and neck from radiation.
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Following are recommended shade numbers for various jobs.

<table>
<thead>
<tr>
<th>No.</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Light gas welding</td>
</tr>
<tr>
<td>5</td>
<td>Minimum for spot welding and flame cutting</td>
</tr>
<tr>
<td>6</td>
<td>Gas welding/cutting/arc welding to 30 amps</td>
</tr>
<tr>
<td>8</td>
<td>Heavy gas welding/arc welding to 75 amps</td>
</tr>
<tr>
<td>10</td>
<td>Arc welding and cutting 75-200 amps</td>
</tr>
<tr>
<td>12</td>
<td>Arc welding and cutting 200-400 amps</td>
</tr>
<tr>
<td>14</td>
<td>Arc welding and cutting over 400 amps</td>
</tr>
</tbody>
</table>

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