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AWS Promotes Diversity

AWS values diversity, advocates equitable and inclusive practices, and engages its members and stakeholders in establishing a culture in the welding community that welcomes, learns from, and celebrates differences among people. AWS recognizes that a commitment to diversity, equity, and inclusion is essential to achieving excellence for the Association, its members, and employees.

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On the cover: G3 Boats is one of four boat manufacturers based in Lebanon, Mo. Pictured is the all-aluminum, all-welded Bay 20 DLX. (Courtesy of G3 Boats.)
The Resistance Welding Manufacturers Alliance (RWMA), an industry partner of the American Welding Society (AWS), is honored to be a part of the Society in its 100th year. Much has been written about this centennial year, and much has already been said about the AWS, including its rich history, the impact it has made, as well as the services it provides to the welding industry, and it should be proud of these accomplishments. What may not be as well known is that the RWMA has its own long-standing history in the welding industry and continues to grow, advancing its core missions as a part of the AWS.

Founded in 1935, the RWMA has been focused on standards for welding machines and materials, educating the manufacturing industry on the latest technologies and advancements, as well as promoting the resistance welding process. The RWMA was formed out of necessity as the use of resistance welding increased in the quickly growing automotive industry. Resistance welding was not exactly a new technology when the RWMA was formed. The process had already been proven and patented nearly 50 years earlier by Elihu Thompson in 1886 as “electric welding” and had slowly worked its way into manufacturing segments during the growth of industry in America. By the first decade of the new century, various disciplines of resistance welding, including spot, butt joint, and seam welding, were being widely applied to metal joining applications.

By the 1930s, resistance welding had proven to be a highly reliable, widely applied, and low-cost method of joining metals, but had not yet been standardized by the equipment or component manufacturers building welding machines for the high-volume applications now facing the industry. The Resistance Welders Manufacturing Association, as it was first called, worked as a collective of member companies to establish those needed standards. To this day, the RWMA continues to provide that same level of standard as well as promoting new developments and educating the resistance welding workforce.

Today, the Resistance Welding Manufacturers Alliance is an active network of industry professionals that advances resistance welding technologies, supports the highest technical standards for the industry, and shares best practices amongst all its members to shape the future of our industry for the next generations. The RWMA continues to support the resistance welding manufacturing community through documented processes, standards, new advancements, and education.

For many years, the RWMA has provided to the industry the Emmett A. Craig Resistance Welding School that has been the benchmark for resistance welding education. It continues to grow and is held at FABTECH each year, both in the United States and Mexico, and is expanding to regional locations.

In addition, we are working with AWS to support and promote both online educational opportunities and the new Certified Resistance Welding Technician (CRWT) program (aws.org/certification/page/certified-resistance-welding-technician)

The CRWT is a spark for a new generation of knowledgeable resistance welding personnel in the metal joining community. The certification will become the first of its kind for those who operate, maintain, and support resistance welding equipment in plants throughout our industry.

With the RWMA and AWS working together, the BETA test portion of the CRWT was completed at the end of April. We have planned promotion for the introduction of the training and testing by early 2020. It has been a long journey developing the CRWT program, but the launch is in sight for a program we all believe will greatly benefit manufacturing companies, the resistance welding workforce, and our industry for years to come.

The AWS and the RWMA both have much to celebrate this year, and we will continue to work together to support the manufacturers and industries involved in metal joining.
1990

An important step in this country’s attempt to curb acid rain took place on November 15, 1990, when President George H. W. Bush signed new amendments into the Clean Air Act that would force the owners of 110 coal-burning power plants using high-sulfur coal to generate electricity to reduce the emission of sulfur dioxide from their plants. Shown here is the flue gas desulfurization outlet duct at Lower Colorado Authority Fayette Power Project 3. The size of a gymnasium, the interiors of this structure were lined with 50,000 sq ft of Hastelloy® Alloy C-22 sheet panels. In a technique known as “wallpapering,” gas metal arc welding was used in the short-circuiting transfer mode to attach the panels to the walls of the ductwork.

1991

Friction stir welding was developed and experimentally proven at The Welding Institute in the United Kingdom. The process and variants such as friction stir spot welding and friction stir processing are used for industrial applications such as shipbuilding, aerospace, automotive, robotics, and computers. One key benefit was that it allowed welds to be made on aluminum alloys that weren’t readily fusion arc welded. These days, the process is being used for other materials besides aluminum.

1993

On Space Shuttle Endeavor Mission STS-57, pilot Brian Duffy soldered 46 connections on a printed circuit board in space. Welding’s biggest role in the fabrication of the Space Shuttle was welding of the liquid oxygen and liquid hydrogen fuel tanks.

1994 and 1995

The 1994 Northridge earthquake in California and the January 1995 earthquake centered in Kobe, Japan, saw between them thousands of casualties in lives lost and injuries as well as billions of dollars in property damage. This brought about work on how to best repair damaged welded structures as well as presented motivation for researchers to improve engineering of welded-steel structures for the future.

1999

The $3 billion Alliance Pipeline was the largest construction project in North America at the end of the decade. It marked several advances in pipeline construction in the United States when mechanized welding and ultrasonic testing debuted as primary pipeline construction techniques.

Better Welding of Aluminum

Learn the answers to four important questions on this subject

BY MIKAEL D. CARRIERE AND VOLKAN GULSEN

Aluminum and its alloys are highly suitable for many manufacturing applications. Aluminum alloys have been used extensively in the aerospace industry since its inception. They were also broadly accepted in other industries, such as automotive, truck and trailers, shipbuilding, packaging, building and architecture, high-pressure gas cylinders, and many others — see lead photo and Fig. 1. Primary reasons for the use of aluminum alloys in various industries are superb strength-to-weight ratio and corrosion resistance. This is beneficial for most applications within the industry segments described above.

Pure, unalloyed aluminum is a soft and ductile metal and, therefore, is not strong enough for most structural applications. Elements such as copper (Cu), manganese (Mn), silicon (Si), magnesium (Mg), and zinc (Zn) are the main alloying elements added to pure aluminum to create alloys with increased mechanical properties — Fig. 2.
There are significant differences between aluminum alloys and steel alloys that need to be recognized and considered as part of the design process. These include the following:

- Some aluminum alloys are heat-treatable and some are not, while almost all steels are heat-treatable.
- Some aluminum alloys are not weldable using typical arc welding practices, such as gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW). However, almost any steel can be fusion welded if the operator takes the necessary precautions.
- Aluminum welds, including the weld metal and heat-affected zone (HAZ), are usually less strong in comparison to the parent material. In steels, welds are usually at least as strong as the base material.
- Aluminum strength and ductility are not compromised at low temperatures because the ductility increases as the temperature decreases to cryogenic levels. Steels become more brittle with the temperature decrease.
- Most aluminum alloys can be joined by arc welding — Fig. 3. However, certain aircraft-grade aluminum and other special alloys are unweldable using conventional methods. Due to aluminum’s oxide layer, a positive polarity is needed to break up the surface to ensure a proper weld. Aluminum welding typically creates a softened region in the weld metal and HAZ. Occasionally, a heat-treatment process may be implemented when possible to recover some mechanical properties. There are other welding processes aside from traditional arc welding that can be used for aluminum, including friction stir, laser, and ultrasonic welding.

The following four questions address important considerations for the proper welding of aluminum.

1. What processes should be used for better welding of aluminum and its alloys?

With aluminum usage increasing across many industries, manufacturers need to consider the common ways to join these materials. The welds should be performed in a way that will maximize quality without compromising productivity.

Gas tungsten arc welding is generally the preferred process for delivering the highest quality welds. This process uses a nonconsumable tungsten electrode to melt the base metal. Depending on the base material and application, filler metal may be added. Filler metal is added independently, and does not transfer any metal across the arc. With proper use of technique and proper cleaning of the base material, this process offers very low porosity levels. Other advantages of GTAW are exceptional heat input control, smooth weld bead surfaces, no spatter, and reduced fume generation. Considering these benefits, the process lends itself very well to the aerospace industry, where high quality is extremely
important. The downside to GTAW is very low filler metal deposition rates, as well as generally slow travel speeds. It's a process that doesn't lend itself to a high-production environment.

Fortunately, many advancements have been made to GMAW technologies. Gas metal arc welding is now a popular option when quality and productivity are imperative. The major difference with this process is that the electrode is fed constantly, and consumed across the arc into the base metal. However, aluminum is a soft metal, and wire feed can be challenging. For optimal feeding, aluminum feeders should use U-groove drive rolls, proper plastic wire guides, non-steel liners, and the correct inner diameter contact tips. Aluminum GMAW is comparably more productive than GTAW as long as the correct parameters and processes are used to avoid incomplete fusion or porosity.

Ultimately, the decision is based on the user's requirements and priorities. If productivity takes a back seat to weld quality, then GTAW may be the way to go. If you need high production, or a balance of both, then consider GMAW.

2. **When should you consider automation?**

Automating the aluminum welding process can improve productivity, and significantly increase output without modifying the workforce. In addition, the consistency and reliability of the automation process can help decrease the costs related to rework, repair, and overwelding.

With various automation solutions available, determining the applicability and choosing the right solution requires a detailed analysis of the current welding application.

See the sidebar for welding application analysis. Consider this when reviewing the full range of capabilities available from potential automation suppliers.

It's best to look for a full-solution package for aluminum welding automation, because the system needs to be designed around the welding arc, the most critical component. In addition, full-solution providers are experienced at analyzing the application, providing the full package, including the ideal filler metal, integrating the automation in the workflow, and providing post-sale service and ongoing technical support for both the automation system and the welding process itself.

3. **So far we have discussed automation equipment. How about filler metals?**

The alloy that's being welded and the service condition of the final weldment will help determine the proper filler metal. In some scenarios, multiple filler metals can be used. For example, you can weld with the commonly used base material, Alloy 6061, using the two main welding filler metals available in the market, 4043 and 5356. There are various other alloys that can be used, but for the sake of this discussion, we'll focus on 4043 and 5356.

The frequently used 4043 filler metal has a couple advantages over 5356. Because 6061 has a higher cracking sensitivity than many other base metal alloys, using 4043 can help...
Due to aluminum's high thermal conductivity, some limitations with 4043 include the relatively low ductility and the shear strength of the weld when making fillet welds. The difference in groove strength between the two alloys is not significant because the weakest link of a 6061 groove weld using either filler metal is the HAZ of the 6061. For post-anodizing color matching on 6061 base material, avoid using 4043.

On the other hand, some advantages of 5356 while welding on 6061 would include increased shear strength and ductility, as well as increased productivity. It has a higher electrical resistivity than 4043. This means that for a given current, the wire feed speed of 5356 is increased. When you compare 4043 wire feed speed at 200 A with 5356 wire feed speed at 200 A, you see an increase of approximately 33% in the deposition rate with the latter. This also makes welding out of position easier with 5356. Because 4043 tends to be more fluid and used for uphill welds, especially when using constant voltage, it has a greater tendency toward unacceptable weld profiles, as well as undercutting at the toes of the weld.

One other factor that should be considered is the stiffness of the alloy. The 5356 filler metal is stiffer than 4043 when comparing the same diameter of wire. This tends to help feedability, especially if using a push-only gun instead of a push-pull.

4. What's the future of the aluminum welding industry?

As various industries face rigorous requirements for lightweighting, aluminum usage is likely to increase across the board. Industries attempting aluminum fabrication that have traditionally used steel will encounter additional challenges on top of those that already exist. In high-production environments like transportation, productivity is the name of the game. A variety of methods have been aimed at achieving fast, cosmetic, and structurally sound aluminum welds. Due to aluminum's high thermal conductivity, applications with high-ampere processes that use larger than traditional diameters (d > 1.6 mm [1/16 in.]) are likely to increase. On thin aluminum materials (t < 3 mm [- ⅜ in.]), modern waveforms are pushing travel speeds to an excess of 100 in./min.

The need for productivity in combination with a shrinking workforce is pushing the trend toward increased automation for aluminum welding. The automotive industry has been using flexible automation, for welding aluminum, for decades. As automation becomes easier to implement, the adoption rates in aluminum welding industries like process, truck/trailers, and general fabrication are increasing accordingly. Aside from traditional flexible robotics, hard automation systems like gantries for long aluminum welds on joggle joints are drastically improving productivity — Fig. 4.

**Ending Thoughts**

Aluminum has traditionally been used for its high strength-to-weight ratio, but never in applications where strength of steel is required. High-strength aluminum alloys with mechanicals approaching steel have existed for decades. Some common alloy groups, including 7xxx, 2xxx, and even some 8xxx, all face similar arc welding challenges. The same alloying elements that give these materials their excellent strength also result in severe cracking issues in the weld. Furthermore, the HAZ degradation of high-strength aluminum alloys often render their initial purpose obsolete.

Recent developments in new alloys, heat treatments, and particle modifications will eventually make the welding of these alloys possible without sacrificing strength or inducing cracks. Diversification of existing filler metals is also increasing, as manufacturers are producing more alloys like 5556, 5554, 4145, and various other uncommon fillers. The need for unconventional and unique aluminum alloys will become increasingly necessary with specialized applications of cold-wire and hot-wire laser, and additive manufacturing of whole parts.
Introduction: Design for Welding Aluminum

Steel is the most used, and consequently the most welded, metal on earth. In 2013, the mass of supplied steel, recycled and virgin, was 106 million metric tons while aluminum came in a distant second with 6.3 million metric tons. The concepts and methods employed to design structures in aluminum are generally the same as those used with steel or other metals. Welding requirements applicable to welded aluminum structures are provided in AWS D1.2, Structural Welding Code — Aluminum. The stress values recommended for structural aluminum design are set forth in the Aluminum Association’s Aluminum Design Manual: Specifications and Guidelines for Aluminum Structures.

Cast and wrought aluminum products are available in many structural forms and shapes. The designer can take advantage of the low density of aluminum by utilizing available aluminum structural forms. Wrought aluminum alloys are broken down into eight groups, which are categorized by the following alloying element(s) employed: 1XXX, 99% pure aluminum; 2XXX, copper; 3XXX, manganese; 4XXX, silicon; 5XXX, magnesium; 6XXX, silicon and magnesium; 7XXX, zinc; and 8XXX, other alloying elements.

Cast alloys are classified using a similar but not identical 3-digit, as opposed to a 4-digit, system.

1XXX. Commercially pure aluminum has the best electrical conductivity and corrosion resistance. The tensile strength of pure aluminum is usually below 15 ksi (100 MPa). For that reason, it is not commonly used in load-bearing welded structures.

2XXX. The alloying addition of copper increases the strength of aluminum, but decreases its corrosion resistance. The 2XXX series is often used as an aircraft material for its high strength; however, due to its lower corrosion resistance, it is often clad with pure aluminum on one or both sides. Most 2XXX alloys are considered difficult to weld, although some are easily welded.

3XXX. The aluminum-manganese alloys are about 20% stronger than pure aluminum. The workability and corrosion resistance of this alloy make it a good choice for water-carrying applications, siding, roofing, and heat exchangers.

4XXX. Silicon additions in the 4XXX alloy give the material good flow characteristics when forging, as well as a lower melting temperature. The lower melting temperature is one of the reasons that 4043 is a good choice for welding filler material.

5XXX. One of the stronger aluminum alloy families is the 5XXX magnesium alloys. There is a proportional relationship between the strength of the alloy and the content of magnesium. Due to their strength, corrosion resistance, and retention of strength after welding, the aluminum magnesium alloys are used in ship hulls and other structural components, especially when corrosion resistance and strength are needed.

6XXX. By alloying with magnesium and silicon, the 6XXX series has good strength and corrosion properties. 6XXX alloys are also easier to extrude, and for that reason, are often made into extruded shapes. The low-temperature properties are also very good. However, they are fairly crack sensitive.

7XXX. Aluminum alloyed with zinc produces one of the strongest aluminum alloys. Many of the 7XXX alloys are not readily weldable by fusion welding processes. However, similar to the variation in the 2XXX family, there are some 7XXX alloys that can easily be welded. These alloys are one of the primary materials used in aircraft construction and are normally joined with rivets. Work on friction stir welding of these alloys has been conducted to reduce the weight and expense of riveted aircraft components.

8XXX. The 8XXX series is the catch-all category where aluminum alloys that contain other alloying mixtures are placed. Each special alloy in this series has its own composition and application.

Aluminum alloys are strengthened two different ways, heat treatment and cold working. Alloys 2XXX, 6XXX, and 7XXX are heat-treatable alloys. Nonheat-treatable alloys, which are strengthened by cold working, include 1XXX, 3XXX, and 5XXX.

Special Design Considerations

The most significant difference between aluminum and steel that must be considered in the design of welded connections is, unlike steel, when aluminum is arc welded, the heat-affected zone (HAZ) will be weaker (or softer) than either the base or the weld metal. The degree of softening is dependent on the aluminum grade. Overcoming the effects of a weaker HAZ is one of the challenges associated with the design of welded aluminum connections.

Options to deal with the HAZ in aluminum weldments may include selection of proper base material, filler material, or welding process. Changing from a fusion welding process to a solid-state process (i.e., friction welding) can reduce, but likely will not eliminate, the softened HAZ.

Creative joint designs with different weld types can be used to overcome the concerns of the softened HAZs. Proper engineering design minimizes the number of joints and amount of welding without affecting product requirements. This, in turn, results in a good appearance and the proper functioning of the product by limiting HAZs and distortion caused by welding. To eliminate joints, the designer may use castings, extrusions, forgings, or bent or roll-formed shapes to replace complex assemblies. Special extrusions that incorporate edge preparations for welding may provide savings in manufacturing costs. An integral lip can be provided on the extrusion to facilitate alignment and serve as weld backing.

Transverse welds in columns and beams should be located at points of lateral support to reinforce the weld and the HAZ to prevent buckling. The weaker HAZ of longitudinal welds in structural members can be neglected if the softened zone is less than 15% of the total cross-sectional area. Circumferential welds in piping or tubing may reduce bending strength; longitudinal welds usually have little effect on buckling strength when the HAZ is a small percentage of the total area of the cross section.
3 WAYS TO MAXIMIZE YOUR MEMBERSHIP

1 CONNECT WITH OTHERS
- MemberNetwork AWS.org – Access our exclusive, members-only online network and enter an active online community of AWS members who share ideas, discuss technical concerns, and get input and support on welding-related issues.
- Become actively involved in your local AWS Section activities.
- Attend AWS-Sponsored events such as FABTECH USA, Mexico or Canada, Welding Summit, and others.

2 ENJOY NUMEROUS DISCOUNTS
- Receive discounts on technical standards, publications, certifications, education offerings and subscriptions.
- Enjoy reduced admission to AWS-sponsored events and conferences (FABTECH, etc.)
- Get discounted rates on insurance, travel, shipping, AWS logo merchandise and more.

3 ENHANCE YOUR CAREER
- Increase your welding knowledge through AWS online seminars, including code clinics, destructive and non-destructive testing, metallurgy, economics, fabrication math and more.
- Get certified by the organization that sets the standards including Certified Welder, Welding Inspector, Welding Educator, Engineer, Sales Representative and more.
- Stay informed with complimentary subscriptions to Welding Journal (monthly), American Welder (quarterly) and Welding Marketplace (twice annually).

There’s no time like the present to start taking full advantage of your membership! Spread the news and invite others to join!

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