200 years on and aluminum is going strong

Aluminum has come a long way since it was first produced in 1824. A mainstay in consumer goods, machinery and equipment sectors, as well as electrical engineering and other industries, aluminum is pervasive.

Today, construction and transportation sectors account for a hefty 52% of global aluminum consumption, with automotive and aerospace applications driving the metal’s growth as never before. In North America, demand for aluminum appears to be insatiable. By 2016, the latest year for which statistics are available, demand for aluminum had hit a seventh straight year of growth, according to the US Aluminum Association. Within that seven-year period, aluminum demand grew by an impressive 41%.
Worldwide, aluminum consumption is second only to steel. Since 2000, global aluminum consumption has exceeded production roughly every other year.

But what are the implications for metalworkers who work with aluminum? Despite sustained inroads into key industries, aluminum is unlikely to ever fully replace steel. Yet challenges that metalworkers experience with steel are just as present in aluminum. And, there are many shop-floor challenges unique to the lightweight metal.

ALUMINUM’S STRENGTHS AND WEAKNESSES

As with all materials, the “metal with wings” has advantages and disadvantages

Aluminum’s high strength-to-weight ratio has long made it an obvious choice in automotive and aerospace sectors because of fuel-efficiency advantages, lightweight properties, corrosion-resistance and many other practical benefits. Although aluminum is not the strongest of metals, alloying it with other metals (copper, magnesium, tin, zinc) helps increase its strength, durability and mass.

Aluminum alloys are easily workable but, as with any fabrication material, there are advantages and disadvantages. On one hand, cast aluminum products are relatively low-cost due to aluminum’s low melting point. On the other hand, they have lower tensile strengths. Additionally, aluminum alloys will warp at high temperatures. They have lower fatigue limits than steel and weaken with repeated stress, which is why aluminum alloys are rarely used in high fatigue-tolerance applications such as girders in building construction and railways.

SHOP-FLOOR CHALLENGES WHEN WELDING ALUMINUM

Common problems and unique challenges for aluminum metalworkers

While the industrial benefits of aluminum are impressive – recyclable, military-grade durability, corrosion-resistance, lightweight and energy-efficient – aluminum can pose a unique set of challenges for metalworkers. In terms of pre- or post-welding problems, aluminum shares some common ground with steel, but not always. Aluminum conducts heat six times faster than steel and has a low melting point, making it very susceptible to warping and burn-through. Aluminum wire has relatively low tensile strength, which can pose wire feeding issues and lead to weld defects if correct equipment is not used. Common aluminum weld defects are spatter, porosity, cracking and lack of fusion.

Porosity

Porosity occurs when hydrogen enters the weld pool during melting and then gets trapped in the weld during solidification. Shielding gas will protect a molten weld pool from the surrounding atmosphere – which can contaminate the weld – but other best-practices must be followed, such as correct gas flow rates and purge cycles. Use of low-dew-point gases should also be a consideration.

Spatter

Weld spatter, or slag, are droplets of molten metal or non-metallic materials that splash during the welding process. These tiny bits of hot material can stick to the base material or any surrounding metallic material. The main causes of these imperfections are typically poor surface preparation and incorrect equipment settings. For metalworkers, spatter – which is generally caused by a disturbance in the weld pool – is an unnecessary and costly nuisance.

Smut and discoloration

Without following an array of best practices, the presence of smut – especially during gas tungsten arc welding (GTAW) – is all but inevitable when welding aluminum. All welds, whether produced by GTAW or gas metal arc welding (GMAW), should be bright and shiny. Smut is black, which is why many welders assume it is carbon or a sooty contaminant. In fact, x-ray analyses have proven weld smut to be a combination of aluminum and magnesium.

Discoloration and smut occur when aluminum or magnesium oxides collect on the base material and weld. As the boiling points of aluminum and magnesium are
lower than the temperatures of a welding arc, aluminum and magnesium in weld filler metal actually evaporate during welding and condense on the cooler base metal if not adequately protected by shielding gas.

**Cracking**

“Hot cracking” is a matter of chemistry. Stress or “cold” cracking is the result of mechanical stresses. Yet small or big, a crack is a defect that could lead to a failed weld inspection because – over time – a crack can result in weld failure. The prevention of hot cracking is possible by using high-quality filler metals with lower crack sensitivity. Cold cracking (during weld cooling) can occur within a day of welding, usually due to trapped hydrogen in the weld via the weld pool. If excessive shrinkage stresses are present during solidification, due to a concave bead profile, a too-slow travel speed or depression in the end of the weld (crater crack), stress cracks will emerge.

**Burn-through**

Burn-through is caused by applying too much heat to aluminum and burning a gap in it. Since welding requires enough heat to fuse the metals properly, burn-through occurs when a welder fails to balance heat and speed. To prevent burn-through when TIG welding aluminum, weld at a low amperage, with a long point on the electrode. When MIG welding, use a gun that pulses (This is a good practice for 1/8-inch or thinner aluminum). Electrical pulses provide enough heating and cooling at proper intervals to prevent burn-through. If welding thick aluminum, set amperage high enough to penetrate the weld joint adequately. For example, 250 amps to weld 1/4-inch thick material and 350 amps to weld 1/2-inch thick material. Consider adding helium to the shielding gas mixture as it provides a hotter, more penetrating arc on thicker sections.

**Lack of fusion**

Lack of fusion or “cold lapping” is a common defect in aluminum welds and often caused by the presence of aluminum oxide (which is insoluble in molten aluminum) on weld surfaces. Poor welding technique can also prevent fusion. This occurs when the voltage or wire feed speed is too low or if the welder’s travel speed is too fast. Because aluminum conducts heat faster than steel, it is prone to lack of fusion at the start of a weld until enough energy is put into the weld. Some welding equipment addresses this automatically by increasing the current at the start of a weld and then lowering it to avoid heat build-up. An excessively wide weld joint can also prevent fusion but can be resolved by narrowing the joint or directing the weld arc towards the side wall of the base plate.

**BEST PRACTICES FOR WELDING ALUMINUM**

**Ceramic pre-weld coatings make welding aluminum problem-free**

Ceramic coating technologies are among the latest powerful tools in the arsenal of aluminum metalworkers. As with steel, weld spatter can be problematic in aluminum welds. If hot spatter fuses to welding nozzles and tips, the resulting clog inhibits shielding gas from flowing freely. Poor gas flow can cause porosity, inconsistent welds or welds that require complete reworking. Applicators such as E-WELD Nozzle™ coat welding nozzle surfaces and prevent spatter adherence and nozzle obstructions. This allows shielding gas to flow freely, heat feeding wire evenly – and ultimately enable better quality welds. It is a powerful solution that lasts up to eight hours, so it is...
from a gel-based solution, one Walter E-WELD Nozzle™ customer saw an 81% reduction in annual nozzle replacement and treatment costs and an 80% reduction in spatter removal labor costs.

Beyond torch nozzles, workpieces can also be protected from spatter to ensure not only clean welds but eliminate costly reworks. E-WELD 4™ is a premium anti-spatter emulsion that protects workpieces from spatter. Compatible with aluminum, stainless steel and steel, it guarantees porosity-free welds and helps prevent weld cracking. It is VOC-free, solvent-free, silicone-free and biodegradable. Crucially, E-WELD 4™ retracts in the presence of heat, leaving welding areas free of liquid. Do not underestimate the value of pre-weld cleaning E-WELD Nozzle™ and E-WELD 4™ are powerful anti-spatter products, yet there are additional measures to optimize aluminum metalworking conditions. The value of pre-weld aluminum cleaning cannot be understated. Bad shielding gas or bad wire can cause porosity, but so can lack of pre-weld cleaning. Two steps come into play: First, it is crucial to remove all oils, greases, lubricants, solvents and other hydrocarbons from the base material in the aluminum weld area. These contaminants contain hydrogen. If they get into the welding arc, they cause weld porosity.

POST-WELDING

Today’s electrochemical weld cleaning technologies make more sense

Welding aluminum poses unique challenges. Defects such as porosity or cracking are common concerns, which is why Walter is committed to pre-weld products that eliminate these fabrication problems. But what of post-weld problems such as discoloration, weld smut or heat tint on heat-affected zones?

When Walter introduced the SURFOX™ 305 in 2017 – a fifth-generation electrochemical weld cleaning system for stainless steel and aluminum – the company had high-volume metal fabrication shops in mind. That, and organizations with a need for quality and safety. Where aluminum cleaning is concerned, there’s been a move away from traditional wire brushes and harsh chemical cleaning solutions in favor of efficient, environment-friendly electrochemical technologies.

Wire brushes are fast but can scratch aluminum and alter finishes. Strong chemicals (pickling pastes) can clean welds but, depending on their type, cause surface damage. Health hazards and expensive disposal issues also come into play.

SURFOX™ is a safe, electrochemical and pH-neutral solution that won’t damage aluminum or stainless steel. On a fresh aluminum weld, it is not uncommon to see the presence of black oxide – a residue that needs to be cleaned. And metalworkers want fast cleaning processes that won’t alter surfaces.

The SURFOX™ 305 will clean a weld at a rapid rate of three to five feet per minute. The device uses a pH-neutral electrolyte solution, pumped directly to the surface being cleaned, and the dynamic electrical current control prevents micro-pitting on weld surfaces. In fact, the SURFOX™ 305 is the industry’s fastest MIG and TIG weld cleaning system.

Compared with toxic pickling pastes, which require at least an hour of application prior...
to removal, it’s easy to see the advantages of non-toxic electrochemical cleaning. Pickling involves strong acidic solutions of nitric and hydrofluoric acids. You have to apply the paste, wait an hour for it to work, and then rinse it off the metal. Costly environmental compliance measures come into play if special wastewater disposal techniques are required, which usually are with toxic acids. Some fabricators pay as much as $8 per liter to dispose of pickling paste and associated liquids.

Electrochemical weld cleaning makes more economic, environmental and safety sense than costlier, traditional and sometimes toxic methods.

The SURFOX™ 305 weld cleaning system for aluminum and stainless steel:

- Removes heat tint from heat-affected zones of MIG, TIG and spot welds
- Allows passivation of stainless steel
- Operates in AC mode for cleaning or marking
- Operates in DC mode for polishing and etching
- Operates with an integrated vapor dispersion system

Today, Walter’s SURFOX™ products are used safely and effectively in several areas including: energy and manufacturing industries, naval and transportation sectors, as well as food and beverage and pharma-ceutics industries.

THE SCIENCE BEHIND ABRASIVES DESIGNED FOR ALUMINUM

Cutting, grinding, blending and finishing aluminum

When it comes to blending or finishing aluminum alloys, keep productivity and safety in mind. Enduro-Flex Alu™ flap discs can be good options. They offer the industry’s longest life and fastest removal rates for flap discs designed for aluminum and other non-ferrous alloys. Their special abrasive blend and size provide smooth and fast material removal. Additionally, they are guaranteed not to clog.

In fact, Walter’s ENDURO-FLEX™ line outperforms all competitive flap discs thanks to its innovative design and exclusive abrasive grain blend. Featuring an Eco-Trim backing that can be trimmed back to extend disc life, ENDURO-FLEX™ is the longest lasting flap disc in the industry and removes more material than any competitive flap disc. Metalworkers will spend more time getting the job done and less time making trips to the tool crib.

When grinding or cutting aluminum, it is important to use high-performance equipment that won’t add unnecessary steps to jobs. Walter’s ALU™ grinding and cutting wheels won’t clog or glaze when working with aluminum and other non-ferrous metals. Because they are free of waxes and lubricants, there is no need to clean work surfaces or apply a coating before welding, which saves valuable preparation time.

For quick cuts on aluminum and other non-ferrous alloys, consider the long-life ZIP ALU™ cut-off wheel. Its special abrasive blend provides smooth, cool cuts that won’t clog when working with aluminum.

CONCLUSION

Where there’s aluminum, there’s a solution to work better

Working with aluminum alloys can throw up all manner of shop-floor challenges – be they pre-weld or post-weld. For fabricators looking to prevent weld defects, innovative solutions are at hand. For metalworkers seeking safe and efficient methods to remove heat tint and discoloration from MIG, TIG and spot welds, electrochemical cleaning and polishing technologies offer outstanding approaches towards correcting weld defects in an environment-friendly manner.

In terms of cutting, blending and polishing aluminum alloys, there has never been a better range of high-tech choices to enhance productivity and maximize safety on today’s shop floor. Walter Surface Technologies can help metalworkers work better – every step of the way.
About the author

Jonathan Douville, ing., Eng., PMP, is Senior Product Manager, R&D International, at Montreal-based Walter Surface Technologies, a global leader in high performance surface treatment technologies. Prior to joining Walter in 2012, Mr. Douville was Senior Scientist, R&D, at US medical devices, pharmaceutical and consumer goods company Johnson & Johnson. He has deep expertise in the mechanical and industrial engineering sectors, R&D, product design, process engineering, mechatronics and medical devices. A strong business development professional, Mr. Douville holds a degree in Mechanical Engineering from École Polytechnique de Montréal.

About Walter Surface Technologies

Walter Surface Technologies provides innovative solutions for the global metalworking industry. From high performance abrasives, power tools and tooling to industrial cleaners, degreasers and lubricants, Walter focuses on helping its customers work better. Founded in 1952, Walter is established in nine countries throughout North America, South America and Europe. International headquarters are in Montreal, Canada and US headquarters are located in Windsor, Connecticut. Key certifications and awards include ISO 9001: 2008; The Wall Street Journal Award; Deutscher Material Preiz; American Eagle Award; and the CleanTech Cleaning Technology Award.