Welding Training & Certification™: Aluminum GMA (MIG) Welding (WCA03)
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Introduction
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Obligations To The Customer And Liability

The collision repair industry has an obligation to correctly repair the customer’s vehicle. Collision repairs must be performed using:

- recommended or tested procedures from vehicle makers, I-CAR, and other research and testing organizations.
- quality replacement parts and materials.
- repair processes and parts as written and agreed upon in the repair order. If items on the repair agreement are not consistent with the repair order, it can be considered fraud.

Performing proper collision repairs requires using parts and procedures that keep remaining warranties intact.

Collision repairs must restore:

- safety.
- structural integrity.
- durability.
- performance.

Throughout the damage analysis and repair process the repairer and insurer must:

- communicate with each other.
- maintain constant communication with the customer.
- be in agreement with each other and the customer on how repairs will be performed.
- inform the customer of any changes in the repair plan from the original repair agreement, and explain the changes and why they have to be made.

To reduce liability:

- make sure that all repairs are performed thoroughly, correctly and as listed in the damage report.
- follow proper procedures.
- have documentation of required repairs with detailed record keeping available for customers.
Technicians are considered the experts and are expected to be knowledgeable on how to perform a quality repair.

Liability insurance that covers the repair facility may not always cover all damages. For example:

- the policy may not cover faulty repairs, leaving liability responsibility completely on the facility.
- a shop owner may find that repair facility liability coverage may not cover the full amount awarded in a lawsuit. The shop owner would have to pay the difference.

It is difficult to reduce the risk of liability exposure. The part that the repairer can control is the chance of being found at fault. Chances can be minimized by:

- using recommended or tested procedures from the vehicle makers, I-CAR, or other research and testing organizations.
- using quality replacement parts and materials that restore fit, finish, durability, and perform at least as well as the original.
- keeping thorough records.

Keeping thorough records includes more than recording the date, mileage, and pre-existing damage. Record keeping also includes:

- making sure all notes are legible.
- verifying the repairs that were made or not made.
- having the customer sign a waiver for repairs that they do not want performed. Repairers must determine their liability on not repairing safety systems such as restraint and anti-lock brake systems.
- keeping computer printouts or worksheets on file showing wheel alignment readings or vehicle dimensions before and after repairs.
- keeping scan tool printouts and records of computer codes for airbag, anti-lock brake, emission, and powertrain control module (PCM) systems.
• attaching the OEM or other tested procedure printout to the vehicle repair order.
• keeping receipts for all sublet work performed.

Refer to "Video: Topics Off Limits" in the presentation. This video identifies topics that should not be brought up in class.
Module 1 - Terminology, Equipment, And Consumables
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The Welding Event

Learning objectives for this module include:

• explaining what to expect during the course of the welding event.
• identifying the differences between GMA (MIG) welding aluminum and steel.
• identifying the different transfer methods used for GMA (MIG) welding aluminum.
• identifying aluminum GMA (MIG) welding equipment.

As aluminum becomes more prevalent in vehicles, such as with this 2015 Ford F-150, it is important to know how to safely and properly weld aluminum.

Welding aluminum is not necessarily harder than welding steel, it is just simply different. This event is designed to help provide a foundational skill set for welding aluminum.

Welding during collision repairs is not an all-day practice, or even an everyday practice. Having the proper skills to make sound welds is critical for maintaining structural integrity and future crashworthiness of a vehicle. This event provides an opportunity to develop, improve, and verify aluminum welding skills.

Students can expect a hands-on coaching environment.

It will be important to establish what the students should expect for the day. The main areas that will be covered are:

• a discussion on the theory involved in aluminum welding.
• an explanation of the welds and the test criteria.
• an overview of the equipment.
• the hands-on coaching environment. This is where the practicing and testing of the seven welds will occur.
What are your goals?

Timely completion of the event is expected. This means that there should be a reasonable progression of improvement of skills throughout the event.

Ask the students, what are your personal goals for today?

Examples:

- To come away with a better understanding of aluminum.
- Be able to understand various aluminum welding techniques.
- Be able to successfully complete all the welds.
- To refresh aluminum welding skills.
- To share what was learned with other staff members.

The coaching environment should be viewed as a safe place for continual learning. The coaching environment should be considered a safe place for continual learning. During this event, the instructor will be observing technique and providing guidance. This will also include visually inspecting and destructively testing the welds.

The test is not a race, not a competitive event, and it is not a game. Instructors are here to verify the participant's skills as a welder in a collision repair facility.

Explain that coaching will ideally help students to:

- achieve successful, repeatable results.
- recognize weld quality.
- identify and correct weld defects and failures.
- improve welding techniques.
- attain the goal of being better and safer welders.
Aluminum Vs. Steel

Vehicle makers recommend GMA (MIG) welding.

Although they may look similar, steel and aluminum have very different characteristics.

Aluminum can be welded using a variety of processes. There are several advantages of the Gas Metal Arc (GMA), or MIG, welding process for welding aluminum. These include GMA (MIG) welding:

- is widely accepted.
- is the process being recommended by vehicle makers.
- equipment is commonly found in collision repair facilities.
- can be used on a wide variety of aluminum alloys and thicknesses.
- has a good production rate.

There are differences between GMA (MIG) welding aluminum when compared to steel. Aluminum has:

- a lower melting temperature. Aluminum melts at 1,200°F. Steel melts at 2,700°F.
- a faster heat transfer. Heat travels very rapidly through aluminum. It will spread, rather than stay concentrated in a small area. Panel thickness also affects the heat transfer.
- a greater thermal expansion rate. When aluminum is heated, it typically expands at a greater rate than steel.
- no color change when heated. It will appear to change state just before it melts. There is no other indication that the surface temperature is rising.

Aluminum oxide has a higher melting temperature.

Aluminum forms a protective coating called aluminum oxide. This is what makes aluminum highly corrosion resistant. Aluminum oxide:
is self healing and begins to reform instantly if it is removed from the surface.

- has a melting temperature of 3,725°F, which is higher than aluminum.
- must be removed from the aluminum before being welded.
- will lead to contamination of the weld. This contamination is called porosity.

Cold start is very common with aluminum.

A common characteristic of aluminum GMA (MIG) welding is a cold start. Typically, a cold start:

- is at the beginning of the weld.
- is caused by the rapid heat transfer of aluminum.
- will cause a lack of penetration at the beginning of the weld.

Another common characteristic of aluminum GMA (MIG) welding is craters. Craters are typically:

- at the end of the weld.
- caused by the high amounts of heat generated by the time an aluminum weld is completed.
- seen as a sunken or undercut area at the end of the weld. A crater will commonly be a weak spot in the weld.

Aluminum welds can be more sensitive to cracking than steel welds.

Cracks may occur when welding aluminum. Typically, cracking occurs:
• from overheating the aluminum. This is due to the expansion and contraction that occurs.
• more frequently on thicker aluminum.
• more frequently on aluminum castings. Aluminum castings are commonly designed with varying thicknesses and reinforcements throughout, which makes them very rigid.

Shown is an Elektron MultiMig 522 welder.

Shown is a Miller 350P welder.

Shown is a Fronius TransPulsSynergic 2700 welder.

Shown is a Car-O-Liner Migatronic welder.

Shown is a Pro Spot Smart MIG welder.

Aluminum has a greater sensitivity to welder settings when working with different:

• alloys.
• material thicknesses.
• joint types.
Changes in these factors will typically require adjustments to the welder settings.

This Miller 350P has been programmed for pulse spray-arc welding.

This Fronius TransPulseSynergic 2700 has been programmed for 1.2 mm diameter electrode wire.

This Elektron MultiMig 522 has been programmed for aluminum wire and is set up for pulse mode.

This Pro Spot Smart MIG display panel shows how the welder has been set up to begin welding on aluminum.

Aluminum GMA (MIG) welding typically requires equipment with different capabilities than steel. Typically, GMA (MIG) welders used for aluminum:

- generate more amperage (current). This is to compensate for the rapid heat transfer.
- may have specific settings for welding on aluminum.
- may have a different electrode wire feed system.
- may use a spool gun.
- use 100% argon shielding gas.
- have dedicated parts for aluminum electrode wire feeding. Dedicated
parts may help reduce the possibility of cross contamination and galvanic corrosion.

It is important to reference vehicle repair information before welding.

Vehicle makers may have repair information that will specify the:

- type of transfer method preferred.
- electrode wire alloy and diameter that should be used for vehicle repairs.
- weld locations, both where originally located and where to make replacement welds.
- type of weld joints to use for repairs.
- size the replacement weld should be and how far apart replacement welds should be spaced.

I-CAR's Repairability Technical Support (RTS) Portal represents the next era in information sharing with the inter-industry. The user-friendly website is designed to link repair professionals with OEM information and expertise, helping to enable complete, safe, and quality repairs with the click of a button at www.i-car.com/rts.

Transfer Methods

There are four electrode transfer methods:

- short-circuit.
- globular.
- spray-arc.
- pulse spray-arc.

The most often recommended for aluminum is pulse spray-arc.

Globular transfer is usually not recommended for aluminum welding. Globular transfer:

- produces more spatter than short-circuit transfer.
- is more likely to produce weld defects in aluminum.
- does not promote good penetration.
Short-circuit transfer uses lower amperage than other transfer methods.

Short-circuit transfer:

- is primarily used on steel.
- deposits the electrode wire as it touches and short circuits against the base metal many times per second.
- uses lower amperage and voltage than other transfer methods.
- makes a steady crackling sound when correctly adjusted.

Spray-arc transfer uses higher amperage than short-circuit transfer.

Spray-arc transfer:

- uses higher voltage, amperage, and wire speed than short-circuit transfer.
- sprays a tiny stream of molten drops across the arc, from the electrode wire to the base metal. The molten drops are much smaller than the diameter of the electrode wire.
- makes a steady humming sound when correctly adjusted.
- produces a large, more fluid weld puddle due to the higher heat for the same electrode size.
- produces little or no spatter.
- typically requires gun travel speed to be increased after starting the weld. This is due to the higher heat generated using spray-arc transfer compared to other transfer methods.
- is not used on thin aluminum.

Spray-arc transfer can be used in all positions, with the proper size electrode wire, when welding aluminum. It is primarily used on heavier metal, typically 4 mm or thicker.

Pulse spray-arc transfer uses two types of welding current.
Pulse spray-arc transfer uses a background current and pulse current. It is required for automotive aluminum welding. During pulse spray-arc transfer:

- the background current maintains the arc.
- the pulse current “peaks” at higher amperages. This “peak” detaches a droplet from the electrode wire.
- the high current pulses rapidly. High current pulses occur between 60 - 200 times per second.
- electrode wire transfers only during the high current pulses.

Pulse spray-arc transfer allows for cooler welding with good penetration.

Pulse spray-arc transfer:

- allows for cooler welding compared to spray-arc. This is due to the time between low current and high current pulses where the electrode wire does not transfer. This allows cooling while still maintaining the arc.
- may offer less chance of burnthrough on thin aluminum, while still giving good penetration on thicker aluminum.
- produces little or no spatter.
- may allow a larger electrode wire to be used.
- can be used in all positions.

Video: The Sound Of Spray Arc
Refer to Video: Transfer Methods
Sounds in the presentation. This video demonstrates the audio differences between short-circuit, spray-arc, and pulse spray-arc.

Electrode Wire

Which electrode wire to choose depends on the vehicle maker.
5000 series electrode wires will be used for the purpose of this weld event. For repairs, follow the vehicle makers' instructions for specific electrode wire requirements.

Electrode wires are alloys, which means they are aluminum mixed with other elements. Electrode wire is classified in one of four different series, either 1000, 2000, 4000, or 5000, with each number identifying a specific type of filler alloy.

Using the correct electrode wire is critical to the strength and integrity of the weld. Electrode wire alloys commonly used for collision repair include:

- 4000 series, usually 4043 or 4047.
- 5000 series, usually 5356 or 5554.

Electrode wire diameters include:

- 0.8 mm.
- 0.9 mm.
- 1 mm.
- 1.2 mm.

Electrode wire diameter considerations include:

- vehicle maker instructions.
- metal thickness.
- amount of welding current.
- transfer method. Pulse spray-arc transfer can allow thin aluminum to be welded with thicker electrode wire.

- using a small diameter electrode wire may lead to problems with some wire feed systems.

4000 series electrode wire:

- may be identified as AlSi, aluminum silicon, on some welding machines.
- is softer wire which produces a more fluid weld puddle, and provides a better weld appearance than 5000 series electrode wire.
- is typically used for cosmetic panel repairs.
- has a lower tensile strength compared to 5000 series electrode wire.

4043 alloy electrode wire is not compatible with some alloys used on vehicles. The Aluminum Association recommends using 4043 electrode wire when welding 6000 series alloy to 6000 series.
Mercedes-Benz recommends using 4043, 1.2 mm electrode wire for welding on 2006 - 2015 SLS models.

Audi recommends using a 4047, 1.2 mm diameter electrode wire for welding on the 2007 - 2015 vehicles.

General Motors recommends 4043, 0.9 mm diameter electrode wire for welding on the hinge pillar casting on the 2014 and 2015 Chevrolet Corvette Stingray.

Ford recommends using 5554, 1.2 mm diameter electrode wire for welding on the 2015 F-150.

Jaguar Land Rover recommends using 5554 electrode wire for sectioning 5000 series structural parts on their aluminum vehicles.

General Motors recommends 5554, 0.9 mm diameter electrode wire for welding structural repairs on the 2014 and 2015 Chevrolet Corvette Stingray.

5000 series electrode wire:

- may be identified as AlMg, aluminum magnesium on some welding machines. The magnesium will become black soot as it exits out of the shielding gas and burns.
- provides a higher strength weld than 4000 series electrode wire.
- is common in structural repairs.
- may have some cosmetic repair usage.

Refer to Video: Electrode Wire Program Setup in the presentation. This video demonstrates the importance of making sure the welder is programmed for the correct electrode wire that is loaded into the welder.
The best welding results are obtained by using clean electrode wire. When not in use, electrode wire should be stored to slow oxidation in a:

- warm, dry area. Condensation may form on cold wire when it meets warmer air.
- sealed plastic bag.

Like all aluminum, avoid contaminating the electrode wire. Using clean electrode wire will help reduce weld porosity.

Aluminum electrode wire has no specifications for the amount of cast and helix. Cast is the curvature of a length of welding wire caused by winding on the spool. Helix is how much a cut length of welding wire springs up when placed on a flat surface.

**Electrode Wire Feed Systems**

A spool gun:

- has a spool of wire attached directly to the welding gun.
- uses one motor and drive roll set attached directly to the gun body.
- has a short liner, contained inside the gun.
- may have limited access to welding areas due to its size.
- may have a flexible end to help increase accessibility.

A push-pull feeder:

**Push-pull feeders are able to use longer cables.**
• has two motors and two sets of drive rolls. One set of each is in the power source cabinet and in the welding gun.
• allows for a longer cable length.
• works well with soft electrode wire. A push-pull feeder also provides uniform feeding for small diameter electrode wire.

Setting drive roll tension correctly is critical. Some welding machines use two sets of drive rolls inside the power source cabinet to help cut down on birdnesting.

A push feeder, similar to what is used for most steel GMA (MIG) welding applications:

• has the feed motor and drive rolls located in or on the power source cabinet.
• pushes the electrode wire through a flexible gun liner and into the welding gun.
• uses a liner that is usually limited to less than 3 m. Aluminum wire tends to buckle and bind at the drive rolls when using long liners. This can cause birdnesting.

Wire feed drive roll designs vary with the type of wire feed system being used.

Knurled drive rolls are typically used in spool guns and pull feeders. Knurled drive rolls are not recommended for push feeders. The knurling may cause aluminum to flake off the wire, causing resistance in a long liner.
U-shaped drive rolls are typically used in push feeders.

V-shaped drive rolls are not recommended for push feeders. V-shaped drive rolls typically compress aluminum electrode wire. Compressing the electrode wire may cause birdnesting.

Contact tips may be marked with AL or ALU (left) and should be slightly recessed in the nozzle outlet (right).

The contact tip:

- is usually made of copper or copper alloy.
- should be recessed about 3 - 5 mm in the nozzle outlet. Some welding guns may be recessed more than that.
- may become worn, reducing current transfer efficiency and causing the electrode wire to wander. Change the contact tip when the hole diameter becomes worn.
- may be oversized. This is done to prevent the wire from seizing in the tip due to expansion from heat during the welding process.
- may be marked with an AL or ALU to indicate that it is a contact tip specific for aluminum GMA (MIG) welding.

Gun liners must be dedicated for aluminum.

The welding gun liner for aluminum electrode wire:

- may be nylon or Teflon, which helps the wire slide with less resistance.
- must be dedicated for aluminum.
- should be blown out with clean, dry compressed air to remove aluminum particles. Electrode wire tends to leave small particles that can build up and affect electrode wire feed and possibly weld quality. Follow the equipment maker’s maintenance instructions.
Shielding Gas

100% argon gas is recommended when welding aluminum.

100% argon is used for aluminum GMA (MIG) welding. A mixture of argon and helium should not be used because it typically welds hotter. This makes penetration harder to control on thin aluminum. Pure argon provides:

- good cleaning action.
- a stable arc.
- better control of penetration on thinner aluminum.

Flow meters are generally set to 25 - 50 cfh for aluminum collision repair welding. This compares to 25 - 30 cfh for steel. This range depends on the type of transfer method, thickness of the aluminum, and nozzle size used. Before attaching the regulator, open the cylinder valve for a second or two to blow out any dirt or contaminants that may be near the valve opening.

The nozzle directs the shielding gas to the weld zone. Tapered shielding gas nozzles are commonly used for welding in the collision repair industry. The tapered ends allow for better visibility of the weld joint.

Inspect and ensure that the shielding gas nozzle is clean. This will help keep the shielding gas flow unrestricted.

Straight shielding gas nozzles are generally used for welding on thick aluminum at a higher amperage. Straight nozzles are used to envelop larger bead and joint areas and deliver more gas flow.
Reverse polarity is also referred to as DCEP.

Reverse DC polarity, when the electrode is positive and the workpiece is negative (DCEP), is used almost exclusively for aluminum GMA (MIG) welding.

With reverse polarity, 80% of the arc heat is at the electrode. Reverse polarity is used for aluminum welding because it provides:

- the highest concentration of heat, which is needed for aluminum.
- narrow heat focus zones.

For improved weld quality and ease of use when welding aluminum, some equipment makers have GMA (MIG) welding machines that are specifically designed for aluminum welding. Aluminum-specific welding machines:

- have higher amperage capabilities to allow spray transfer. An output of 200 amps at 30% duty cycle is recommended.
- typically come equipped with a spool gun, a push-pull feeder, or a dual-drive roll electrode wire feed system. This allows for use of a wider variety of electrode wire diameters and alloys.
- may have pre-programmed settings for welding aluminum. Settings for different alloys and diameters of electrode wire may be available. Some machines may have settings for different thicknesses of aluminum and joint configurations. Features to reduce cold start and crater defects are also programmed in some welding machines.
- typically use pulse spray-arc transfer.

The Fronius 2700 welder shown on the screen uses a liquid-cooled torch. The welder can run at 100% duty cycle, with a maximum output of 400 amps. The Fronius 2700 has programs for specific joints on specific vehicles, such as a 3 mm butt joint with backing on a 2004 - 2010 Jaguar XJ.
Module Wrap-Up

Topics discussed in this module included:

- what to expect during the course of the welding event.
- the differences between aluminum GMA (MIG) welding compared to steel.
- the different transfer methods used for aluminum GMA (MIG) welding.
- aluminum GMA (MIG) welding equipment.
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Module 2 - Welding Preparation, Tuning, And Techniques
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Surface Preparation

Learning objectives for this module include:

- identifying how to properly prepare aluminum alloys for GMA (MIG) welding.
- describing the different technique variables when aluminum GMA (MIG) welding.
- determining how to tune a GMA (MIG) welder to weld aluminum.
- describing techniques specific to aluminum GMA (MIG) welding.
- identifying weld defects, causes, and correction methods.
- describing practices used in collision repair facilities for aluminum GMA (MIG) welding.

Aluminum oxide:

- forms on the surface of bare aluminum, protecting the aluminum from further corrosion. Oxide can be compared to the zinc coating on steel, in that the oxide protects the aluminum from deterioration.
- will begin to re-form immediately on the surface, if removed.
- can trap moisture and dirt. A thick layer of oxide tends to hold more dirt and moisture than a thin layer.
- can cause porosity in an aluminum weld bead.

Every area of the weld joint must have coatings and oxide removed.

Poor welds occur from aluminum surfaces that are contaminated. This may include coatings and aluminum oxide, which must be removed about 30 - 40 mm from the weld joint. Every area of the weld joint should be thoroughly cleaned, including the backside and the edges.

Leaving coatings, aluminum oxide, or any contaminants too close to the weld zone may cause defects in the weld.
Shown are the various items used to remove coatings and aluminum oxide.

The coatings and aluminum oxide are removed using a:

- wax and grease remover first to remove any residue. Sanding before using wax and grease remover smears the contaminants into the surface of the aluminum.
- plastic woven pad or disc sander with 80 - 120 grit sandpaper. Sandpaper can also be used by hand to access small hard-to-reach areas.
- stainless steel wire brush.

Use abrasives dedicated for use on aluminum. Abrasives used for steel may contaminate an aluminum surface.

If a disc sander is used, do not press too hard. Excessive sanding pressure may:

- remove too much aluminum, thinning the metal. Thinning the metal may also lead to warping from overheating.
- clog the disc. Using a clogged disc on aluminum may scratch or gouge the surface.
- imbed impurities into the surface.

Do not use mild steel brushes for oxide removal. Mild steel brush particles may flake off, contaminating the aluminum.

Weld-through primers should not be used on aluminum.

After cleaning, avoid handling the surfaces to be joined with bare hands. This may contaminate the clean surface and adversely affect weld quality.
Weld as soon as possible following part fit-up and cleaning.

After cleaning the aluminum, the aluminum oxide forms relatively quickly on the surface. This is the self-healing feature of aluminum alloys. Welding should be done as soon as possible following part fit-up and cleaning. The weld joint should be cleaned again with a small stainless steel brush immediately before welding. The amount of time that can pass before complete re-cleaning is required will vary with temperature and humidity levels.

**Technique Variables**

The welding gun is pointed and pushed away from the weld puddle. The push technique is also called forehand or lead angle by the American Welding Society (AWS).

- helps direct the shielding gas to the front of the weld puddle.
- provides an arc cleaning action to remove aluminum oxide from the surface.
- is done straight. The welding gun is not weaved back and forth on the joint. Weaving will change where the arc is being focused.

The pull technique, also called the drag or backhand with drag, is when the welding gun is pointed at and dragged away from the weld puddle. This type of technique is not used for aluminum because it:

- increases the chance of porosity and a poor weld by not providing enough shielding gas and cleaning action.
- may cause the joint to be rough, or have large amounts of black soot on the weld bead.
- may overheat the weld area, causing excessive penetration.
The gun angle for pushing does not need to be excessive.

Welding gun angle for the push technique:

• should be about 5 - 15° from vertical.
• does not need to be excessive, such as 45° from vertical. Angling the welding gun too far back may cause a loss of shielding gas effect at the front of the weld. Too much gun angle may also draw contaminants in from the backside of the welding gun, due to a vacuum effect.

If a butt joint with backing is being made in two passes, it should be treated as two fillet welds. Students may do the butt weld with backing either way for the I-CAR Welding Training & Certification™.

The contact tip-to-workpiece distance should be about 10 - 16 mm.

Work angle affects where heat is directed.

The work angle:

• affects where the heat is directed to the joint.
• varies by different welding joint designs.
• for butt joints or butt joints with backing is 90°, directed at the center of the root.
• for fillet welds, also known as lap joints, using the same thickness of aluminum, is 45°, directly at the root. When a fillet weld has two different thicknesses of aluminum, the work angle should be directing more heat on the thicker panel. This may help reduce burning away of the thinner aluminum.

• should be about 10 - 16 mm.
• may help control bead height. Varying the contact tip-to-
workpiece distance may also affect penetration along a continuous weld.

- is an important factor for pulse spray-arc welding, as this affects the arc length.
- will affect stick-out. Contact-tip-to-workpiece, wire speed, and voltage will affect stick-out.

Travel speed may need to be increased no matter which transfer method is used when working on thinner aluminum.

![Travel speed example](image1)

**Shown is the result of a travel speed that is either too slow (top) or too fast (bottom).**

Travel speed:

- affects penetration and overall weld bead dimensions.
- varies by the transfer method being used. The travel speed typically needs to be increased as the weld progresses when using the spray-arc transfer method. This is from the constant high amperage being used. For pulse spray-arc, the travel speed can remain more constant. This is from the cooler welding action of the pulsed current.

Body positioning can affect how well you see the weld.

Body positioning is one of the most overlooked factors with all types of welding. When aluminum GMA (MIG) welding, it is very important that a technician can fully see the area to be welded. Reading glasses or a magnifying lens for the welding helmet may improve a technician’s ability to see the joint while welding.

Being able to see more clearly may help with:

- better gun control.
- arc direction to focus the heat where it is wanted.

Magnifying lenses for welding helmets are commonly referred to as “cheater lenses.” Cheater lenses are typically available at welding supply stores and are available in different strengths of magnification.
Tuning The Welding Machine

The Miller 350P has a chart on the welder to provide an initial program setting.

The Fronius TransPulseSynergic 2700 amperage is being adjusted.

Amperage adjustments are being made on the Elektron MultiMig 522.

The Car-O-Liner Migatronic amperage setting is being adjusted for the material thickness.

Once the material thickness has been adjusted, the new amperage / voltage setting will not show up on the welder until the arc is struck on the Pro Spot Smart MIG.

Amperage and voltage settings used for GMA (MIG) welding aluminum vary depending on:

- electrode wire diameter and alloy. Larger diameters and higher alloy series will typically require higher amounts of amperage and voltage.
- material thickness. The thicker the aluminum is, the higher the amperage required.
- joint type. Different joint types typically require different amounts of amperage and voltage.
Some welding machines have charts for the technicians to find a starting point that can be used for making practice welds. Determining the required amperage setting is important to determine if the welding machine being used is capable of supplying the necessary amperage for a given thickness of metal. For thinner metal, it will help to know that maximum amperage is not required to produce a quality weld.

Increasing or decreasing amperage affects the heat of the weld.

Adjusting the amperage, or current, is the same as increasing or decreasing the wire speed. An increase in amperage will make the weld hotter. This will increase penetration and make a larger weld bead.

Decreasing the amperage will make the weld cooler. This will decrease penetration and make a smaller weld bead.

Adjusting the amperage to the material is typically the first step in tuning the welding machine.

The voltage setting is automatically adjusted as the amperage is set on synergic welders.

Voltage affects the rate in which the electrode wire burns. Changes made to the voltage when aluminum GMA (MIG) welding typically affects the arc length. The arc length is the distance that the electrode wire is burning from the surface of the workpiece. Too much voltage may result in burnback to the contact tip.

Synergic welding machines adjust voltage automatically when the amperage is changed.

Arc length affects the distance the electrode wire is burning from the workpiece.

Arc length adjustment:
• is typically an independent adjustment on pulse spray-arc welding machines.
• is typically a fine-tuning adjustment.
• affects weld penetration and bead dimensions.
• negatively, makes the electrode wire burn closer to the surface of the workpiece. A decrease in arc length will result in increased penetration, but make the weld bead narrower.
• positively, makes the electrode wire burn farther away from the surface of the workpiece. Increased arc length decreases penetration, but makes the weld bead wider.

Refer to Video: Tuning The Welder - Miller 350P in the presentation. This video demonstrates that initial pre-programmed settings may need adjustments and that the person welding needs to be prepared to make those determinations.

Refer to Video: Tuning The Welder - Elektron MultiMig 522 in the presentation. This video demonstrates how to make adjustments to the initial setup of the welder.

Refer to Video: Tuning The Welder - Pro Spot Smart MIG in the presentation. This video demonstrates how to make adjustments to the initial setup of the welder.
Welding Techniques

A hot-start function on some welders will help avoid a cold start (inset).

A major concern when welding aluminum is poor penetration at the beginning of the weld. This is called a cold start. Cold start is caused by the rapid heat transfer characteristic of aluminum.

If the welder has a hot-start function, this can be avoided. A hot-start function will boost the amperage at the beginning of the weld to heat the aluminum quicker. Some welders that have a hot-start function use a time setting for how long the hot start stays on.

With most welders, it is necessary to compensate for the cold start.

One method to compensate for a cold start is to start the weld off the joint and move into the joint after the arc is established, sometimes called “tailing in.” This can be used for any weld.

Practice will help in making consistent weld beads.

Good weld bead consistency is key for making strong aluminum GMA (MIG) welds. Key items for achieving good weld bead consistency include:

- keeping the same work angle on the joint throughout the weld.
- keeping the same gun distance from the joint throughout the weld.
- travel speed. Spray-arc transfer typically requires an increased travel speed while making the weld. A more even travel speed can be used when while making the weld using pulse spray-arc transfer.
Crater Fill Welder Setting

A welder with a crater fill setting decreases the current at the end of the weld.

There are techniques to fill craters, which are common at the end of an aluminum weld. Techniques for avoiding craters include:

- speeding up slightly when approaching the end of the weld, and then backtracking onto the weld bead.
- stopping the weld and pausing to let the weld bead cool briefly, then restriking the arc and filling the crater.

Some welding machines have settings for a crater fill. Crater fill settings allow the welder to drop the amperage down gradually when approaching the end of the weld bead.

Refer to “Video: Filling Craters” in the presentation. This video shows how to fill a crater at the end of a aluminum weld bead.

Run-on and run-off tabs can be used for start and stop areas.

Besides helping to align a joint and provide strength, a backing strip may be used on an aluminum butt joint to provide “run-on” and “run-off” tabs.

Run-on and run-off tabs:

- may be an extension of the backing.
- may be separate tabs welded on at the ends of the joint.
- are used as areas for the weld to be started and stopped.
• keep the cold start area of the weld from being made on the panel.
• moves the crater out of the repair area.
• are removed after welding.

A visual inspection should be completed on all welds.

Initial visual inspection after making an aluminum GMA (MIG) weld includes looking to see whether:

• the joint is completely filled.
• the crater is filled at the end of the weld.
• the weld bead has good width and height dimensions.
• penetration is evident, but not excessive melt-through or heat mark on the backside.

Weld appearances can be deceiving.

This butt joint with backing appears to be a good weld. There is a flat and consistent bead on the face and evidence of penetration on the backside along the full length of the joint. This does not ensure that the weld will pass destructive testing.

A destructive test of this weld shows there was no fusion to the top coupons.

Destructive testing of practice welds will help to verify if changes will need to be made to technique and / or if adjustments will need to be made to the welder. Practicing on like material thickness and joint configuration will help ensure a good repair.
Welding Defects

Cold welds may appear to be sitting on the surface.

A cold weld:

- appears as too much weld metal build on the surface.
- has little or no evidence of penetration.
- has little or no fusion to the workpiece.
- is usually caused by the amperage set too low.
- can occur from using a travel speed that is too fast.

Too much heat can weaken the surrounding aluminum.

Too much heat can:

- cause excessive penetration.
- cause burnthrough on the workpiece.
- weaken material by permanently softening the surrounding area.
- be caused by an amperage setting that is too high.
- be caused by a travel speed that is too slow.

Suck-back looks like a crater on the backside.

Suck-back is when the weld bead shrinks back during cooling to form a crater on the backside of the weld. Suck-back:

- is usually found on overhead welds.
- can result in weakening the weld bead or base metal.

Some techniques to prevent suck-back include:

- reducing the settings on the welding machine.
- slightly increasing travel speed.
- on butt joints, reducing the root gap during fit-up.
Incompatible filler alloys may cause cracks.

Though not common with aluminum welds, cracks or fracturing of an aluminum weld can occur if there is:

- too much amperage or voltage used.
- the wrong alloy electrode wire.
- rapid cooling.
- improper joint fit-up, causing internal stress.
- inadequate penetration, causing weld failure from fatigue.
- inadequate weld bead.

An undercut weld:

- will look as if the weld bead is lower than the edge or edges of the top workpiece.
- typically has lack of fusion to the top workpieces.
- is commonly caused by a travel speed that is too fast.
- on a butt joint with backing weld can be caused by a root gap that is too wide.

Undercut welds look lower than the edge or edges of the top workpiece.

Improper work angle affects heat focus.

Using an improper work angle:

- will direct the arc incorrectly.
- will not focus the heat where it is wanted.
- may cause a lack of fusion between the workpieces.
- may cause excessive penetration and suck-back. For example, a fillet weld where the work angle is focused on the bottom piece may give the weld bead a very shallow, almost undercut appearance and have excessive penetration into the bottom piece.
Inconsistent travel speed and technique can cause inconsistent beads.

A weld bead that is varying in size may be caused by inconsistent:

- travel speed. Speeding up and slowing down will change the width of the weld bead.
- gun distance. Moving the gun in and out will change the height of the weld bead.

Weld beads that wander off the joint are commonly caused by poor body positioning. A technician must be in position to see the area that will be welded.

An aluminum weld that has porosity will appear to have excessive soot on the exterior of the weld bead. A porous weld:

- will appear to have several holes or pores.
- may appear to have less filler material than required.
- will be weak.

Porosity can be caused by:

- the workpiece not being cleaned enough to remove coatings and aluminum oxide.
- a low shielding gas flow rate.
- not pushing the gun.
- using contaminated welding wire.
- using contaminated shielding gas.

Practical Application

Vehicles should be protected while welding.

To avoid damaging the vehicle from welding sparks:
• cover the vehicle with welding blankets or spark paper.
• adjacent parts may be removed.

An induction of current or voltage spikes can destroy sensitive electronic parts. When welding, protect computers and other electronic parts by:

• disconnecting and isolating both battery cables. Remove and isolate the negative battery cable first.
• removing computers or other sensitive electronic parts if welding closer than 300 mm.
• keeping the current path short by placing the ground clamp close to the weld zone.
• keeping the welding machine as far away from the vehicle as possible.
• not allowing welding cables to pass near computers or sensors. Welding cables should run perpendicular to wiring harnesses.

Practice welding is a very important step in the repair process. Practice welding must be:

• done before welding on a vehicle.
• done using the same thickness and alloy of aluminum that is used on the vehicle. Similar joint styles should be constructed and practiced in the same position as will be done on the vehicle.
• destructively tested after passing visual inspection.

Aluminum welding may not be done every day in a collision repair facility. A welding logbook is one way to keep track of welder settings that were successful for a particular application. A welding logbook may help find a starting point for similar repairs that need to be done in the future.

Dress welds where they will interfere with adjacent panel fit-up (left). Epoxy primer is commonly used to coat bare aluminum (right).

Dressing aluminum welds may be done using:

• 50 grit sanding discs.
• aluminum-specific grinding discs.
• light pressure. Light pressure helps prevent clogging of the discs and smearing the aluminum from overheating.

Check vehicle maker instructions for weld dressing.

Finishing aluminum welds typically requires:

• using caution to not thin the surrounding weld area, as this may lead to cracking.
• using a fine tooth body file or P80 grit sanding disc to remove any coarse scratches left by grinding.
• coating the bare aluminum with either a primer or cosmetic filler if it is a cosmetic part. Vehicle makers typically specify products for coating bare aluminum.

Module Wrap-Up

Topics discussed in this module included:

• how to properly prepare aluminum alloys for GMA (MIG) welding.
• the different technique variables when aluminum GMA (MIG) welding.
• how to tune a GMA (MIG) welder to weld aluminum.
• techniques specific to aluminum GMA (MIG) welding.
• weld defects, causes, and correction methods.
• practices used in collision repair facilities for aluminum GMA (MIG) welding.
Module 3 - Welding Training & Certification™: Aluminum GMA (MIG) Welding
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Test Parameters

Learning objectives for this module include describing:

- visual inspection criteria of butt joint with backing, fillet, and plug welds.
- destructive testing criteria for the welds.

The I-CAR Welding Training & Certification™: Aluminum GMA (MIG) Welding requires a total of four different welds to be completed. Three of the welds are completed in both the vertical and overhead positions.

The Welding Training & Certification™: Aluminum GMA (MIG) Welding event:

- is a method to verify skills of collision repair technicians who are welding aluminum on a daily basis.
- is done on 5000 and 6000 series alloy aluminum coupons in two thicknesses. All coupons are 76 x 127 mm.
- requires four different welds. The three welds to be completed in both the vertical and overhead positions are butt joint with backing 2.5 mm, fillet, and butt joint with backing 1 mm. The fourth is the plug weld, which is to be completed in the vertical position only.

Recognition will be provided when all welds are successfully made.

Participants who pass the Welding Training & Certification™: Aluminum GMA (MIG) Welding (WCA03) event receive:

- a letter congratulating them on successfully passing the Welding Training & Certification™: Aluminum GMA (MIG) Welding.
- a Certificate of Completion.
The I-CAR Aluminum GMA (MIG) Welding Gauge is used to visually inspect all of the test welds. The gauge measures minimum and maximum:

- face and melt-through height.
- bead width.
- nugget diameter.
- bead length.

Butt Joint With Backing Weld 2.5 mm

The butt joint with backing weld is done using three 2.5 mm coupons.

The butt joint with backing weld for the test is made on three 2.5 mm, 5052-H32 alloy coupons. When fitting up the butt joint, butt two coupons edge to edge, and center the third coupon behind the joint. Keep a root gap between the two top coupons about 2 - 3 metal thicknesses. Root gap will depend on if the weld is being done in one or two passes.

The participants are required to make a continuous weld, centered on the joint, in the vertical and overhead positions. If the butt joint with backing is being made with two passes, it should be treated as two fillet welds. Tack welds are not allowed. Coach the butt joint with backing weld with the participant until successful, repeatable results are achieved.

Visual requirements for the face side of the butt joint with backing 2.5 mm weld include:

- no cracks, porosity, skips, or undercut.
- the joint and crater are completely filled.
- a bead length of 57 - 76 mm.
- a bead width of 10 - 16 mm.
- a bead height no greater than 2 mm.
Visual requirements for the backside of the butt joint with backing 2.5 mm weld include:

- no cracks.
- no suck-back, except at the stop point.
- a melt-through width no greater than 3 mm.
- melt-through height no more than 2 mm.

The butt joint with backing weld is a visual failure if any of these requirements are not met.

Welds that pass visual inspection must be destructively tested.

Destructively test the butt joint with backing weld after it passes visual inspection.

Destructively test the butt joint with backing 2.5 mm weld using this procedure:

1. Clamp the weld sample in a vise so one of the top coupons faces the front of the vise, and the weld bead is slightly above and parallel to the vise jaw.
2. Use a wide, flat-jawed locking pliers to bend the upper coupon back and forth until it breaks free from the backing.
3. Reverse the weld sample in the vise and, similarly, break the remaining coupon from the backing.
4. Inspect each face coupon for metal tearout. Also inspect the weld bead. The weld is good if there is metal tearout on each of the face coupons for the length of the weld and the weld holds firm on the backing piece. The coupons, and not the weld, should break to pass the butt joint with backing weld.
Fillet Weld

The fillet weld uses two coupons that are different thicknesses.

The fillet weld for the test is made on two thicknesses of coupons, a 1 mm, 6061 T6 alloy coupon and a 2.5 mm, 5052 H32 alloy coupon. The 1 mm coupon is lapped about halfway over the 2.5 mm coupon's length.

The participants are required to make fillet welds centered on the lap joint in the vertical and overhead positions. Tack welds are not allowed. Coach the fillet weld with the participant until successful, repeatable results are achieved.

- no cracks, porosity, skips, or undercut.
- the joint and crater are completely filled.
- a bead length of 57 - 76 mm.
- a bead width of 5 - 10 mm.
- a bead height no greater than 2 mm.

The backside of the weld is being inspected for excessive melt-through.

Visual requirements for the backside of the fillet weld include:

- no cracks.
- no suck-back, except at the stop point.
- a melt-through width no greater than 3 mm.
- melt-through height no more than 2 mm.

If the weld area does not meet the visual criteria, it does not have to be destructively tested. The fillet weld is a visual failure if any of these requirements are not met.

Visual requirements for the face side of the fillet weld include:

The weld bead length is being checked.
Welds that pass visual inspection must be destructively tested.

Destructively test the fillet weld using this procedure:

1. Clamp the bottom, 2.5 mm coupon in a vise so that the top, 1 mm coupon is above and parallel to the vise jaws.
2. Bend the 1 mm coupon until it breaks off from the 2.5 mm coupon.
3. To pass inspection, there must be metal tearout from the 1 mm coupon for at least the length of the weld and the weld holds firm on the backing piece. The coupon, and not the weld, should break to pass the fillet weld on lap joint test.
4. Inspect the weld bead on the bottom, 2.5 mm coupon. The weld should hold firm for at least the length of the weld.

Butt Joint With Backing Weld 1 mm

The butt joint with backing weld for the test is made on three 1 mm, 6061-T16 alloy coupons. When fitting up the butt joint, butt two coupons edge to edge, and center the third coupon behind the joint. Keep a root gap between the two top coupons about 2 - 3 metal thicknesses.

The participants are required to make a continuous weld, centered on the joint, in the vertical and overhead positions. Tack welds are not allowed.

To achieve the required penetration, it is important to begin the weld by using the tailing in technique. Tailing in will place the cold start off the joint and allow for proper penetration within the joint. This will reduce the possibility of the weld bead separating from the back coupon when it is destructively tested.

If the welding machine is equipped with the hot start feature and the participant is familiar with it, the feature may be used.
Coach the butt joint with backing weld with the participant until successful, repeatable results are achieved.

Visual requirements for the face side of the butt joint with backing 1 mm weld include:

- no cracks, porosity, skips, or undercut.
- the joint and crater are completely filled.
- a bead length of 57 - 76 mm.
- a bead width of 5 - 10 mm.
- a bead height no greater than 2 mm.

Visual requirements for the backside of the butt joint with backing 1 mm weld include:

- no cracks.
- no suck-back, except at the stop point.
- a melt-through width no greater than 3 mm.
- melt-through height no more than 2 mm.

The butt joint with backing weld is a visual failure if any of these requirements are not met.

Welds that pass visual inspection must be destructively tested.
Destructively test the butt joint with backing weld after it passes visual inspection.

The back coupon is destructively tested further.

Destructively test the butt joint with backing 1 mm weld using this procedure:

1. Clamp the weld sample in a vise so one of the top coupons faces the front of the vise, and the weld bead is slightly above and parallel to the vise jaw.
2. Use a wide, flat-jawed locking pliers to bend the upper coupon back and forth until it breaks free from the backing.
3. Reverse the weld sample in the vise and, similarly, break the remaining coupon from the backing.
4. Inspect each face coupon for metal tearout. Also inspect the weld bead. The weld is good if there is metal tearout on each of the face coupons for the length of the weld and the weld holds firm on the backing piece. The coupons, and not the weld, should break to pass the butt joint with backing weld.
5. Grasp the back coupon on each end, bend both ends back. The
weld bead should not lift off the back coupon.

**Plug Weld**

The plug weld uses two 1 mm coupons.

The plug weld for the test is made on two 1 mm 6061-T6 alloy coupons. One of the coupons has an 8 mm punched hole in one corner. This coupon is lapped onto the corner of the other coupon, at 90° to each other.

The participants are required to make an 8 mm plug weld in the vertical position. Tack welds are not allowed. Coach the plug weld with the participant until successful, repeatable results are achieved.

The I-CAR Aluminum GMA (MIG) Welding Gauge is used to measure the weld nugget size.

Visual requirements for the face of the plug weld include:

- no cracks, porosity, skips, or undercut.
- the crater and hold are completely filled.
- a nugget height no greater than 3 mm.
- a nugget diameter of 11 - 15 mm.

The backside of the weld is being inspected for excessive melt-through.

Visual requirements for the backside of the plug weld include:
• no cracks.
• a melt-through diameter is at least 3 mm but no larger than 8 mm.
• a melt-through height at least level (no suck-back) with the bottom, but no higher than 3 mm.

The plug weld is a visual failure if any of these requirements are not met.

Welds that pass visual inspection must be destructively tested.

Destructively test the plug weld after it passes visual inspection.

Destructively test the plug weld using this procedure:

1. Clamp the bottom coupon in the vise so the face of the weld faces the front of the vise.
2. Keeping the two coupons parallel to each other, twist off the top coupon until it breaks free from the bottom coupon.
3. There must be a tearout hole in the bottom coupon at least 5 mm in diameter.

Safety

Appropriate safety gear must be worn while welding.

For this event, participants must have:

• a welding helmet with plastic lens cover.
• welding gloves.
• safety glasses, which must be worn under the helmet.
• a welding respirator.
• leather-cape welding sleeves. (optional)

Shown are some of the required tools.

Additionally, participants must have:

• side-cutting pliers.
• regular pliers.
• locking pliers.
• an I-CAR Aluminum GMA (MIG) Welding Gauge.
• a stainless steel wire brush.
• auxiliary lighting (optional).

Q. Why wear a respirator? Isn't that the purpose of the ventilation system?

A. It is a necessary piece of safety equipment. Welding fumes can get into lungs and cause respiratory problems. Breathing the fumes in for a length of time can lead to Parkinson's disease.

Q. What about the helmet? What strength of filter plate should there be?

A. At least 11

Q. Why safety glasses? Doesn't a helmet take care of that?

A. Sparks can get inside a helmet and into your eyes. Also, wearing safety glasses is an OSHA requirement in the shop area for everyone.

Q. Why say "cover" before striking an arc?

A. This makes everyone in the immediate area aware to take safety precautions.

Q. What is the purpose of hearing protection? Welding isn't that loud, is it?

A. Any environment where you have to shout to be heard requires hearing protection. Also, this is ear protection from sparks that get under the helmet.

Q. What about in your pockets, what can't you have?

A. Matches, lighters, anything a spark could set off

Q. What should be nearby the welding area?

A. A fire extinguisher

Refer to Video: Safety Overview in the presentation. This video provides an overview of safety considerations within the repair facility environment.

Module Wrap-Up

Topics discussed in this module included:
• the test parameters of the I-CAR Welding Training & Certification™: Aluminum GMA (MIG) Welding event.
• visual inspection criteria for the butt joint with backing, fillet, and plug welds.
• destructive testing criteria for the welds.
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