Welding Process for Automotive After-treatment Hardware

Jonathan Zhang
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Materials

- 300 series stainless steel for pipes and fabricated manifolds - SS309 or SS304
- 400 series ferrite type stainless steel for sheet metal stampings, flanges and some pipe applications - SS409, SS439, 18CrCb
- 400 serial ferrite type stainless steel powder metallurgy products - Flanges
- Heat resistant ductile cast irons - Manifolds
- Low carbon steel - hanger rods
Weld Joints

- 360 degree circumferential lap joint between can / manifold and can / pipe
- Vertical fillet joint – pipe / flange
- Thin wall sheet metal lap joint - shoebox
- Thin wall sheet metal seam joint - clamshell
- Thin wall sheet metal to pipe or another thin wall sheet metal spot welding or MIG tack welding joint - heat shield attachment
- Thin wall sheet metal edge joint - small flange
Welding Anatomy

Composite Region

Unmixed Zone

Partially Melted Zone

Weld Interface

True Heat-Affected Zone

Unaffected Base Metal
Welding Anatomy

Zone characteristics

- **Weld deposit or composite zone** – a mixture of weld wire and base metal at solidification structure, which is totally different from base metal

- **Heat affected zones** – base metal composition with significant micro structural changes from the original wrought base metal, this will lead to a reduced mechanical properties, and sometimes a significantly reduced properties
Welding Anatomy
Welding Processes

- There are four major welding processes for automotive after-treatment system welding operations
  - MIG welding - majority
  - Resistant seam welding – clamshell design
  - Resistance spot welding - internal cone to shell
  - Plasma arc welding - pipe/flange joint
MIG Weld

- Setup
MIG Weld

- Flux cored wire is used once adopted by shoebox welding
MIG Weld

Welding Operation Parameters

- Current - current type as well
- Voltage - arc length
- Travel Speed
- Welding position - uphill or downhill or horizontal
- Shield gas composition and flow rate
- Type of weld wire
- Diameter of weld wire
- Weld torch orientation
MIG Weld

**Torch setup**

- (1) Torch handle,
- (2) Molded phenolic dielectric (shown in white) and threaded metal nut insert (yellow),
- (3) Shielding gas diffuser,
- (4) Contact tip,
- (5) Nozzle output face
MIG Weld – Flux Cored Wire

Advantages of flux cored wire:
- In-expensive compared with solid wire
- High deposition rate
- Deeper penetration
- More fluid weld pool
- Better tolerance with dirty parts

Disadvantages of flux cored wire:
- More spattering and slag
- More smoke and fume
Weld Wire Selection

- Three types of wires for exhaust system welding - SS409, SS309 and Ni base wire
- For applications with maximum temperature <1450 F and joints with similar base metal, SS409 solid or cored wire should be used.
- For application temperature >1450 F and/or joints with 300 type/400 type stainless base metal, SS309 wire should be used.
- If cast iron is involved as a base metal, one must select Ni base weld wire
# Weld Wire Selection

## Recommended Wire Sizes

<table>
<thead>
<tr>
<th>Material Thickness</th>
<th>MIG Solid Wire</th>
<th>Gasless Flux-Cored Wire</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.024”</td>
<td>.030”</td>
</tr>
<tr>
<td>24 Gauge (.025)</td>
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<td></td>
</tr>
<tr>
<td>22 Gauge (.031)</td>
<td></td>
<td></td>
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<tr>
<td>20 Gauge (.037)</td>
<td></td>
<td></td>
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<tr>
<td>18 Gauge (.050)</td>
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<tr>
<td>16 Gauge (.063)</td>
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<td></td>
</tr>
<tr>
<td>14 Gauge (.078)</td>
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<td></td>
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<tr>
<td>1/8” (.125)</td>
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<td></td>
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<tr>
<td>3/16” (.188)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/4” (.25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/32” (.313)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/16” (.375)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2” (.5)</td>
<td></td>
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</tbody>
</table>

Multi-pass welding or a beveled joint design may be required on material thickness 3/16” and greater depending on your welding machine’s amperage capability.
MIG Weld – Shielding Gas

Effect of shielding gas on weld bead contour and penetration patterns

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MIG Weld – Torch Angles

- Proper welding angles
MIG Weld - Directions

- Push and drag

![Diagram of weld techniques](image)

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MIG Weld

- Effect of current, voltage and weld speed on welding penetration

![Graph showing the effect of current, voltage, and weld speed on weld penetration.](image)
MIG Weld

- Torch stick-out setup

Electrode Extensions (Stick-out)

- Too Short
- Normal
- Too Long
MIG Weld - Oscillation

- Torch oscillation leads to optimal erosion and abrasion wear resistances
MIG Weld

- Torch aiming position is critically important, as it dictates both metal transfer and heat transfer at the joint.
- If it is not aiming the correct position, the consequences will be:
  - Cold weld
  - Burn through material
  - Mat burning-porosities
MIG Weld – Torch Position

- Torch position effects weld quality

- Gun Position Drift Left
- Correct Gun Position
- Gun Position Drift Right

- Gun Drift Left Causing Burn Through
- Correct Gun Position Good Weld
- Gun Drift Right Cold Weld
MIG Weld – Torch Position

- Factors that effect touch position
  - Welding robot programming
  - Welding robot calibration
  - Welding fixture design and maintenance
  - Converter shell geometrical consistency
  - Production line QC system preparation and enforcement
  - Operator training
MIG Weld Tips

- Keep a 1/4 to 3/8 in stick-out - electrode extending from the tip of the contact tube.
- For thin metals, use a smaller diameter wire. For thicker metal use a larger wire and a larger machine.
- Use the correct wire type for the base metal being welded. Use stainless steel wires for stainless steel, and steel wires for steel.
- Use the proper shielding gas. CO2 is good for penetrating welds on steel, but may be too hot for thin metal.
- Use 75% Argon/25% CO2 for thinner steels, and a triple-mix for stainless steels (Helium + Argon + CO2).
MIG Weld Tips

- Use an AWS classification ER70S-3 for all purpose economical steel welding.
- Use ER70S-6 wire when more deoxidizers are needed for welding on dirty or rusty steel.
- For best control of weld bead, keep the wire directed at the leading edge of the weld pool.
- When welding out of position (vertical, horizontal, or overhead welding), keep the weld pool small for best weld bead control, and use the smallest wire diameter size.
- Be sure to match the contact tube, gun liner, and drive rolls to the wire size that is using.
MIG Weld Tips

- Clean the gun liner and drive rolls occasionally, and keep the gun nozzle clean of spatter. Replace the contact tip if blocked or feeding poorly.
- Keep the gun as straight as possible when welding, to avoid poor wire feeding.
- Keep wire in a clean, dry place when not welding, to avoid picking up contaminants that lead to poor welds.
- Use both hands to steady the gun when hand weld. Do this whenever possible. This also applies to Stick and TIG welding, and plasma cutting. Keep wire feeder hub tension and drive roll pressure just tight enough to feed wire, but don’t over-tighten.
- Use DCEP (reverse polarity) on the power source.
MIG Weld Tips

- A drag or pull gun technique will have a bit more penetration and a narrower bead. A push gun technique will have a bit less penetration, and a wider bead.
- When welding a fillet, the leg of the weld should be equal to the thickness of the parts welded.
- Compare weld to the pictures in the following page to determine proper adjustments.
Weld Quality Pictures

- Examples of the weld

![Weld Quality Examples](image)
Welding Challenges

- For exhaust system in production welding operations, design and process challenges include the following:
  - The design nature of thin wall structure
  - Weld gap variation due to the components - from less than 0.2 mm to over 2-3 mm
  - Converter geometrical variation
  - Dissimilar alloy joining operation
  - Mount material organic binder burning & gas formation, mat pinch
  - Control of system setup, welding parameter selection
  - Operator weld training
Quality

- Weld gap problem
  - Weld may not be able to bridge over the gap
  - Weld spattering may enter the converter cavity

- Solutions
  - Correct upstream process to reduce gap from stamping, incoming pipes if possible
  - Modify weld path to oscillation but with a reduced line rate of production
  - Adjust torch position & orientation
  - Change weld parameters to reduce spattering
  - Minimizing human error
Quality

- Production process with high scrap rate failure modes:
  - Thin sheet metal wall burn through
  - Extensive weld porosity
  - Weld discontinuity
  - Cold weld - including undercut, lack of fusion
  - Poor consistency & repeatability due to assembly geometrical variations and welding parameter control problems
  - Welding structural distortion
Quality

- Factors that affect weld quality in summary
  - Welding current, voltage and speed
  - Shielding gas and flow rate
  - Torch path - with or without weld gun oscillating
  - Welding torch working angle and push/drag angle
  - Welding torch aiming position
  - Type of the weld wire and stick out length
  - Welding position
Quality - Metallurgy

- Ferrite types of stainless steels do not enjoy high welding heat input.
- Excessive heat input significantly reduces the toughness of the base metal in the weld heat affected zone.
- More weld deposit and excessive weld penetration do not lead to stronger weld joint, it weakens the joint!
Quality

- Improve the production floor welding system’s operational robustness with focus in:
  - Fine tuning the system parameters
  - Select suitable weld wire for particular application
  - Vary welding position to accommodate the technical challenges
  - Reduce human factor/error in the weld quality equation
  - Conducting operator training
Other Considerations

- Residual Stress

Before Weld

After Weld

Residual Stress and Distortion

Before Weld

After Weld

Residual Stress with Restriction Weld

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Recommendations

- Change shoebox converter welded to certain angle down hill direction will help increasing weld robustness significantly
Design Change

- Current production part is similar like this.

[Image of a metal cylinder and a sponge-like object]
Design Changes

- Design change on clamshell structure with clamping force applied and angled welding position.

A max. gap

MIG Weld

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Design Change

Advantages of clamshell converter with an angled position welding:

- Reduced weight
- Higher productivity - Welding speed increased
- Design for Robustness with larger operation window
- Significantly reduces mat burning & weld porosity
- Make weld torch aiming issue less critical
- Eliminate can wall burn through issue
TIG - GTAW

Manual GTAW (gas Tungsten Arc Welding) setup

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TIG Welding

- Use Argon shielding for steel and stainless steel.
- Use DC-Straight Polarity (DCEN) for steel and stainless.
- Always use a push technique with the TIG torch.
- Match the tungsten electrode size with the collet size.
- Steel and stainless steel - use a 2% thoriated tungsten, AWS Class EWTH-2 (red identifying band). Prepare a pointed-end for DCEN welding. Refer to Tungsten Preparation
TIG Welding

- Tungsten preparation

**Correct**
Ideal Tungsten Preparation – Stable Arc

1. Stable Arc
2. Flat
3. Grinding Wheel
4. Straight Ground

Note: Do not use wheel for other jobs or tungsten can become contaminated causing lower weld quality.

**Incorrect**
Wrong Tungsten Preparation – Wandering Arc

1. Arc Wander
2. Point
3. Grinding Wheel
4. Radial Ground

Tungsten Preparation
GTAW Process

- **Direction of weld**
- **GTAW head**
- **Power Shielding gas**
- **Contact tube**
- **Tungsten electrode (nonconsumable)**
- **Electrical arc**
- **Filler rod**
- **Weld bead**
- **Copper shoe (optional)**
- **Shielding gas**
Plasma Arc Welding

Very similar to TIG weld
Plasma Arc Weld vs. GTAW

GAS TUNGSTEN ARC

PLASMA ARC

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Plasma Arc Weld vs. GTAW

- Plasma arc welding has a greater energy concentration as compared to GTAW. A deep, narrow penetration is achievable, with a maximum depth of 12 to 18 mm depending on the material.
- Greater arc stability allows a much longer arc length (stand-off), and much greater tolerance to arc length changes.
- PAW requires relatively expensive and complex equipment as compared to GTAW; proper torch maintenance is critical.
- Welding procedures tend to be more complex and less tolerant to variations, Operator skill required is slightly greater than for GTAW.
- Orifice replacement is necessary.
Resistance Spot Welding

A process in which contacting metal surfaces are joined by the heat obtained from resistance to electric current flow. Work-pieces are held together under pressure exerted by electrodes.

Resistance Spot Welding Process
Resistance Spot Welding

- **Process sequence**
  - Close electrodes and apply force
  - Initiate and maintain welding current
  - Turn off welding current and maintain electrode force until weld nugget solidifies
  - Open electrodes

- **Controls**
  - Current upslope and down-slope controls
  - Current and voltage and electrode force controls
Resistance Spot Welding Tips

- Resistance welding is recommended for use of steel and stainless steel process only.
- For more heat (amperage output), use shorter tongs.
- For exhaust system spot welding, if the units without a heat control, tong length can be used for a control, where if less heat desired, a longer tongs can be used.
- Keep in mind that longer tongs can bend, and lose of pressure at the weld could be seen.
Resistance Spot Welding Tips

- For the metals being welded, make sure there is no gap between the pieces - this will weaken the weld.
- Keep the alignment of the tongs straight, so that the tips touch each other exactly as well as to maintain a proper pressure adjustment.
- When there is a need for one side of the weld to have good appearance, a flatten (machine) tip should be somewhat on that side.
- Clean the tips on a regular basis, for maintaining output (amperage), and dress the tips with a proper tip dresser.
Resistance Seam Welding

A resistance welding process which produces coalescence at the faying surfaces the heat obtained from resistance to electric current through the work parts held together under pressure by electrodes.
Resistance Seam Welding

- **Design Considerations**
  - Nugget size for strength
  - Probability of porosity
  - Desired surface condition of the finished weld

- **Controls**
  - Heating time, cooling time, weld speed
  - Current and electrode force
  - Electrode shape