Aluminum handheld laser welding for cabinets and enclosures

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Primary project objective

Determine handheld laser welding procedures for 5052-H32 aluminum capable of meeting the quality requirements of NAVSEA TP-248/278

- Base metal thickness – 0.063-inch, 0.125-inch, and 0.188-inch
- Joint types/positions – square groove butt joint (1G) and fillet T-joint (2F)
- 0.047-inch ER5356 filler

Project team

- ATI
  - Ryan Schneider
  - Jonathan Roberts (Ingalls)
- SEL (sole performer)
  - Kylan Robinson
  - Heather Jordan
  - Nate Rindal
  - Ryder Gilmore
- NNS – Paul Hebert (retired)
- EB – Vincent Mangino

Laser welding system

IPG Lightweld XR Handheld Laser Welder

- 1,500 W average/2,500 W peak power fiber laser
- Manufacturer claim – can weld as thick as 0.250-inch 5XXX aluminum
- Included cleaning mode

IPG Lightweld Wire Feeder

Original model no longer available from IPG

Follow-on air sampling

Conducted second round of personal air sampling for aluminum in Q3, with results received in Q4

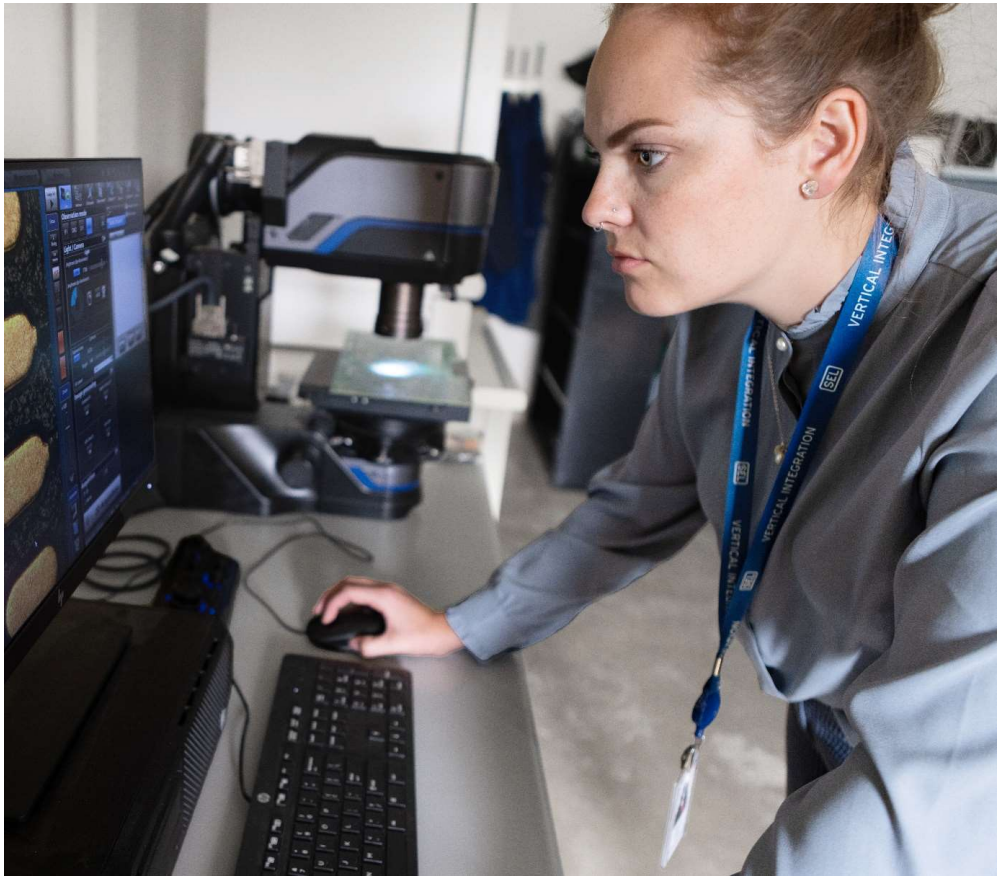
A welding technician wore a pump for sample collection

Particle counter was used to verify ventilation effectiveness

Follow-on air sampling results

Aluminum concentration in breathing zone was magnitudes less than OSHA permissible exposure limit (PEL)

- Measured TWA
  29.62 µg/m^3
- OSHA PEL
  15 mg/m^3
  (15,000 µg/m^3)

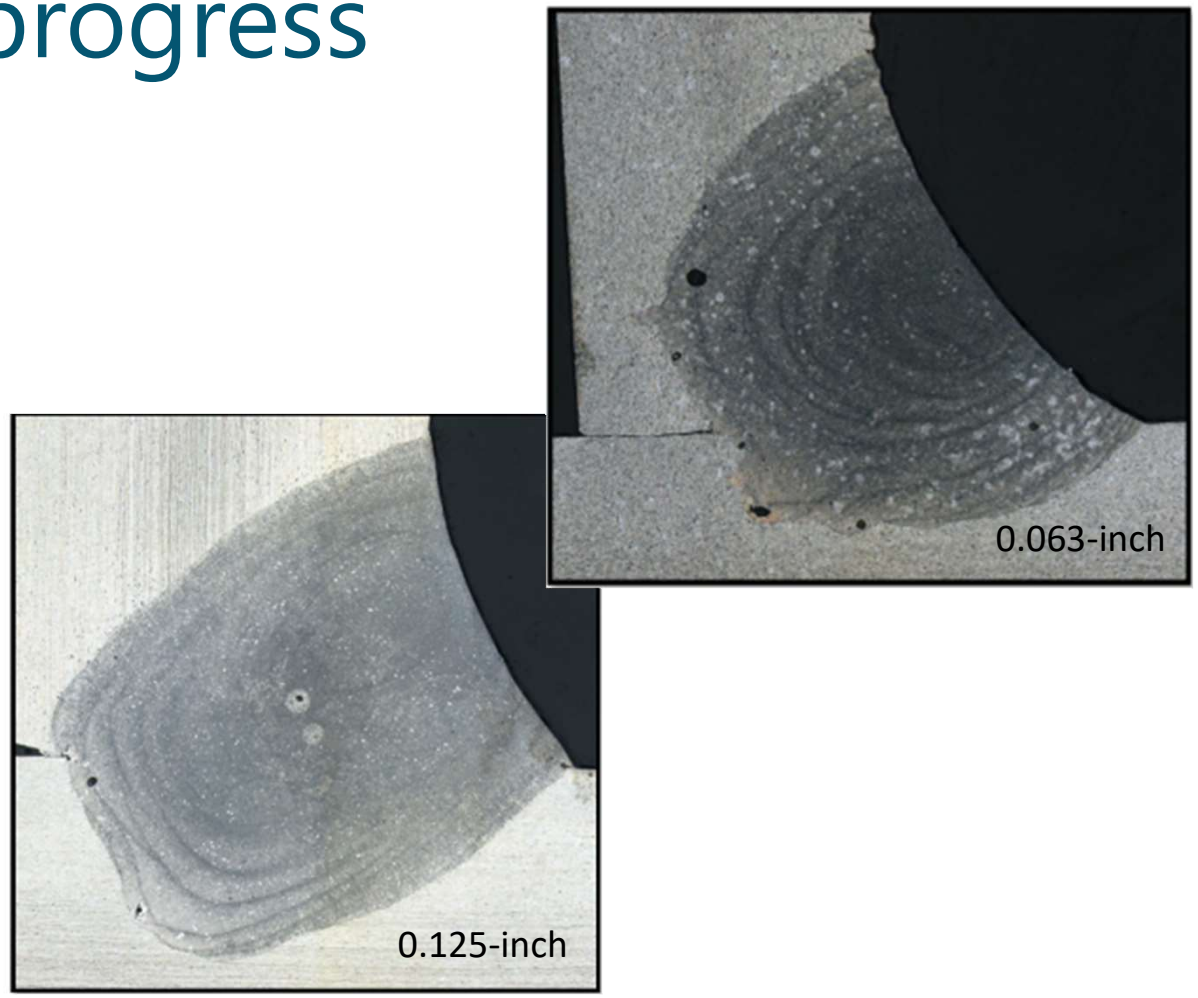


Q3 experiment progress

- Significant fillet weld progress was made in all thicknesses
- Completed 0.063-inch groove weld porosity mitigation Design of Experiments (DOE)

Q3 – fillet weld progress

- IPG's power compensation parameter improved results
- First crack-free cross-sections were produced in all three thicknesses



Q3 – 0.063-inch groove weld DOE was completed

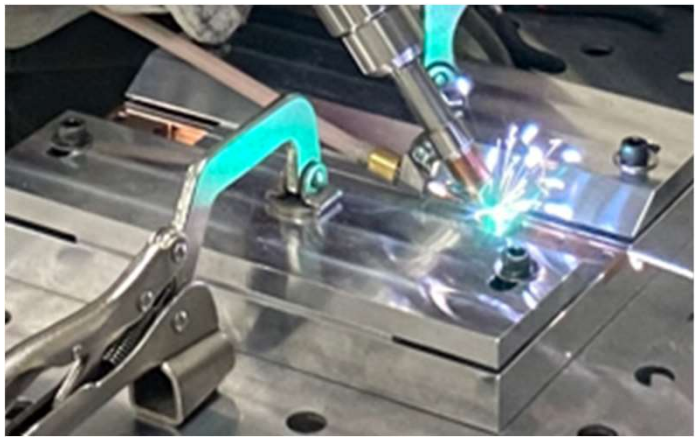
Used Response Surface Methodology (RSM) DOE

Varied five parameters at three levels

- Beam power = 700, 800, and 900 W
- Wobble length = 0.6, 1.1, and 1.6 mm
- Wobble frequency = 30, 90, and 150 Hz
- Wire Speed = 50, 60, and 70 cm/min
- Compensation = 0, 15, and 30%

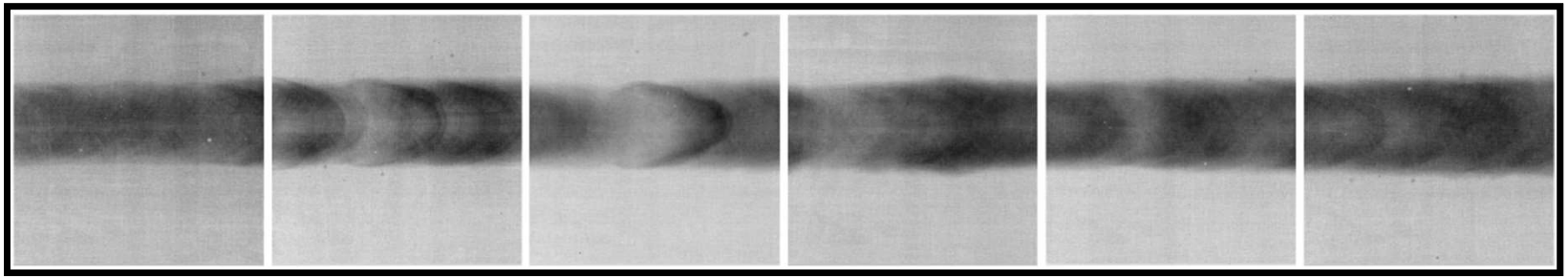
Weld prep process

1. Acetone wipe
2. File and wire brush
3. Acetone wipe



Q3 – 0.063-inch groove weld DOE was completed

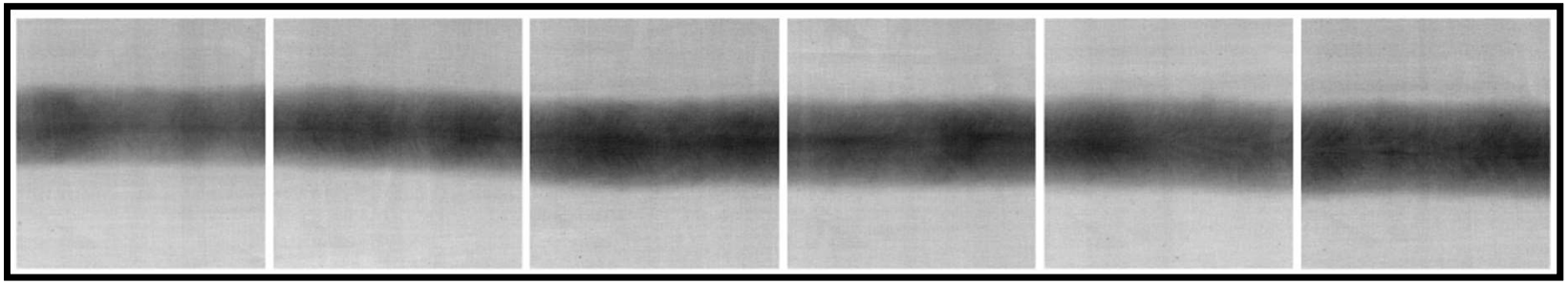
- DOE-identified parameters produced welds with minimal porosity
- Porosity still exceeded MIL-STD-2035 limits



Beam Power [W]	Wobble Length [mm]	Wobble Frequency [Hz]	Wire Speed [cm/min]	Compensation [%]	Gas Pressure [psi]
900	1.6	150	70	9	30

Q3 – further 0.063-inch groove weld experimentation

- Testing using parameters from DOE weld sample with least amount of microporosity showed good results
- No microporosity was found



Beam Power [W]	Wobble Length [mm]	Wobble Frequency [Hz]	Wire Speed [cm/min]	Compensation [%]	Gas Pressure [psi]
900	1.1	90	60	15	30

Q4 experiment progress

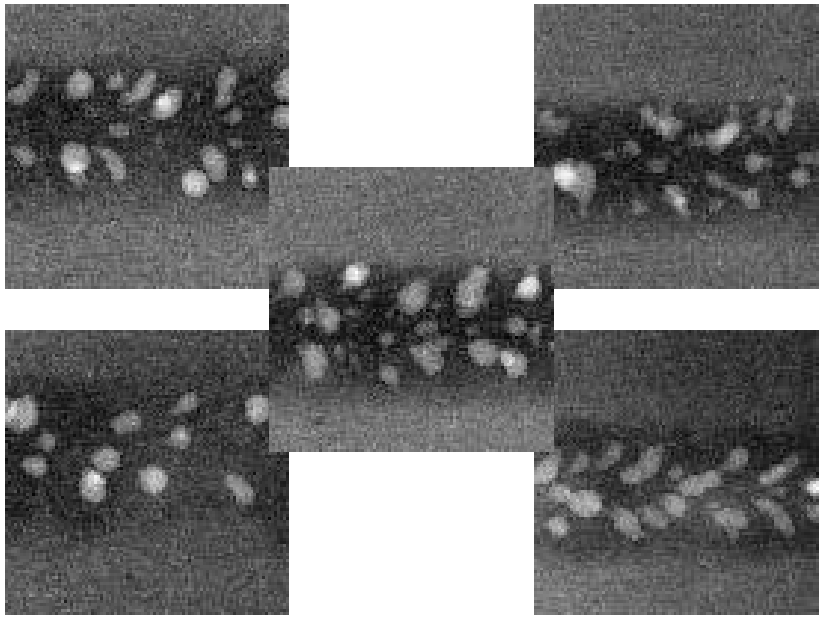
- Conducted 0.188” groove weld porosity mitigation DOE
- Tested final groove weld parameters in fillet weld applications
- Had third-party testing of final weld samples conducted

0.188″ groove weld DOE

- Created RSM DOE samples
  - 24 samples
  - Beam power = 1500 W
  - Wobble frequency = 15–60 Hz
  - Wobble width = 0.5–1.3 mm
  - Wire speed = 50–70 cm/min
- Identified excessive porosity in all samples

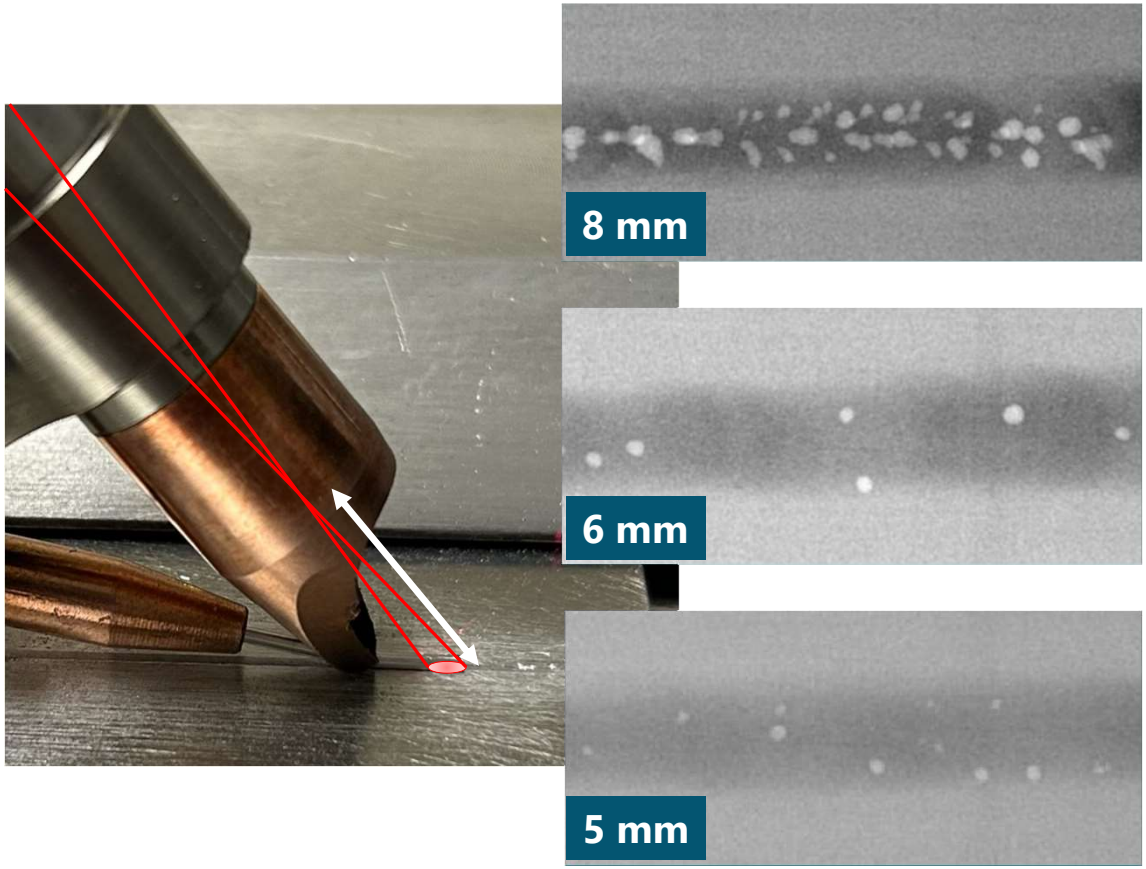
Weld prep process

1. Acetone wipe
2. File and wire brush
3. Acetone wipe



0.188” laser beam defocus testing

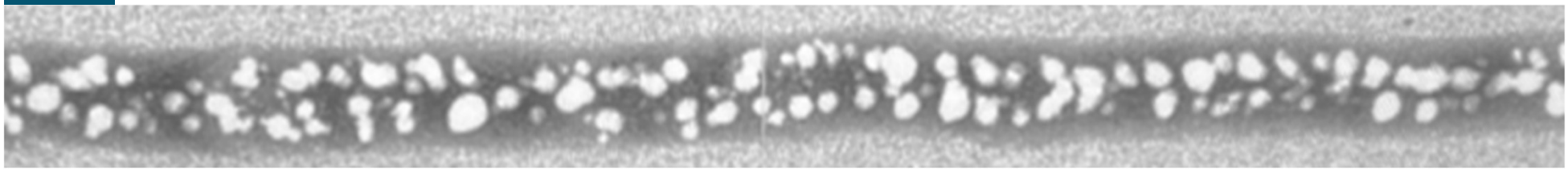
- Baseline defocus
  7 mm
- Increasing beam defocus
  Increases laser spot size
- Decreasing beam defocus
  Reduces laser spot size
- Initial testing showed promise at reducing porosity



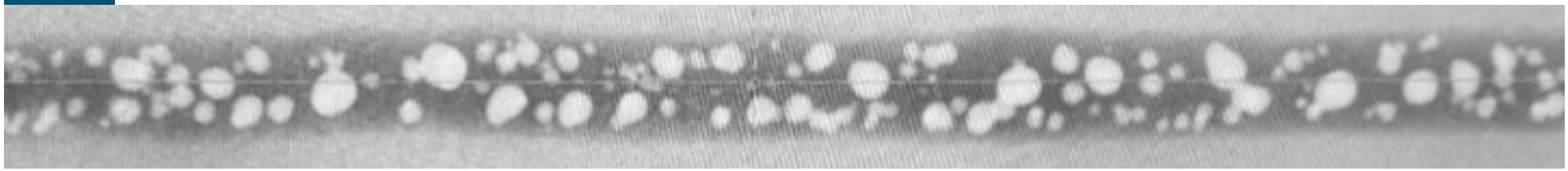
0.188” preheat experimentation

- Did not resolve porosity issues
- Saw increase in pore size with increasing preheat temperatures

150°F

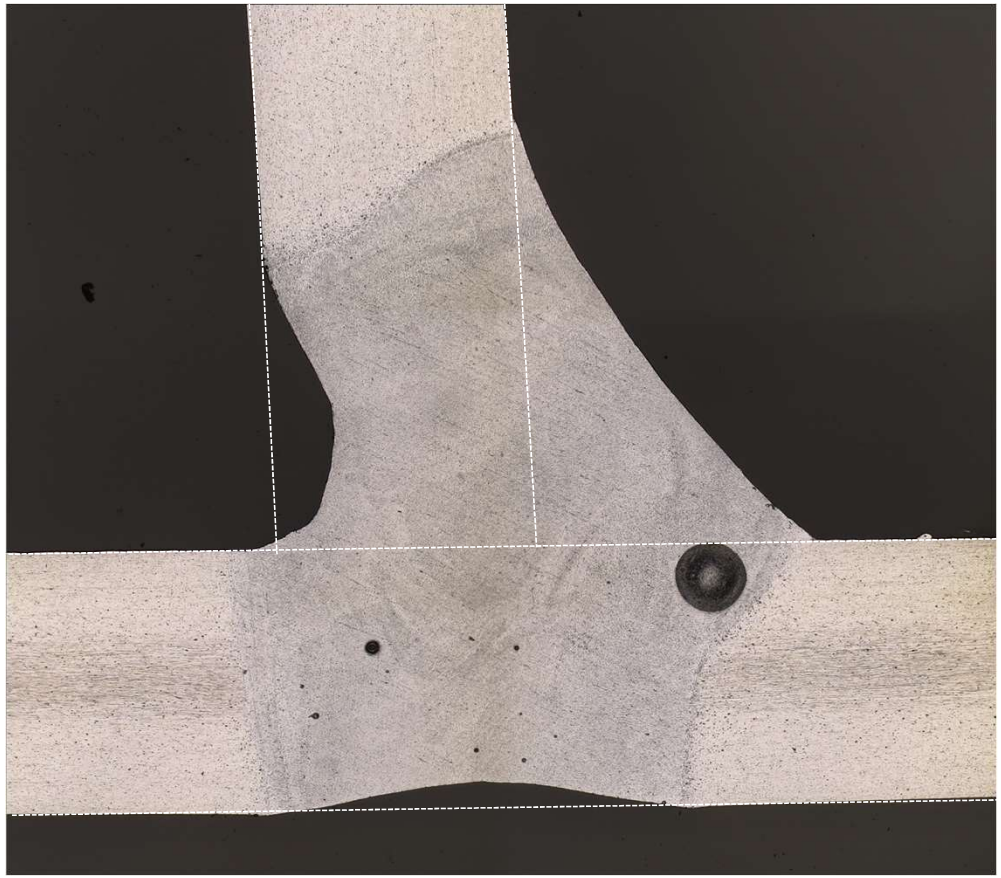


180°F



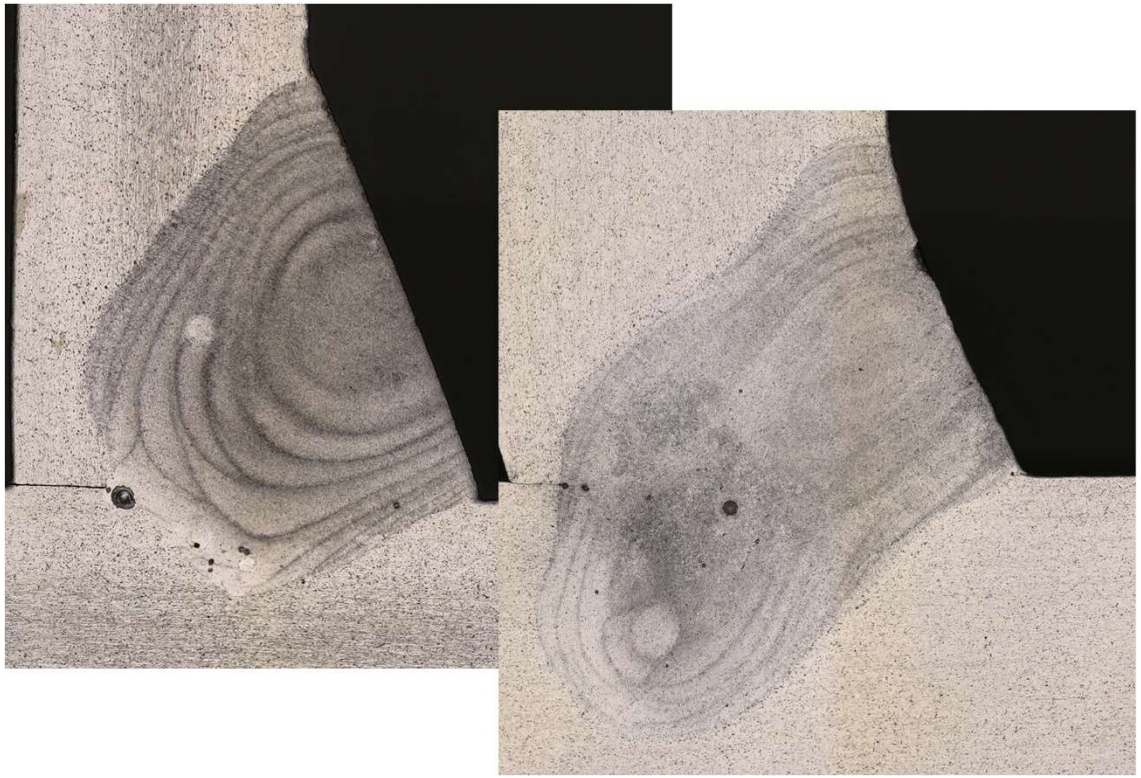
Groove weld parameters in fillet weld applications

- Fillet welds were made using final parameters for 0.063-inch and 0.125-inch groove welds
- Both welds exhibited suck-back from excessive penetration at full power



Groove weld parameters in fillet weld applications

- Power reduced from 900 W to 680 W for 0.063-inch
- Power reduced from 1,400 W to 1,300 W for 0.125-inch
- No cracking observed

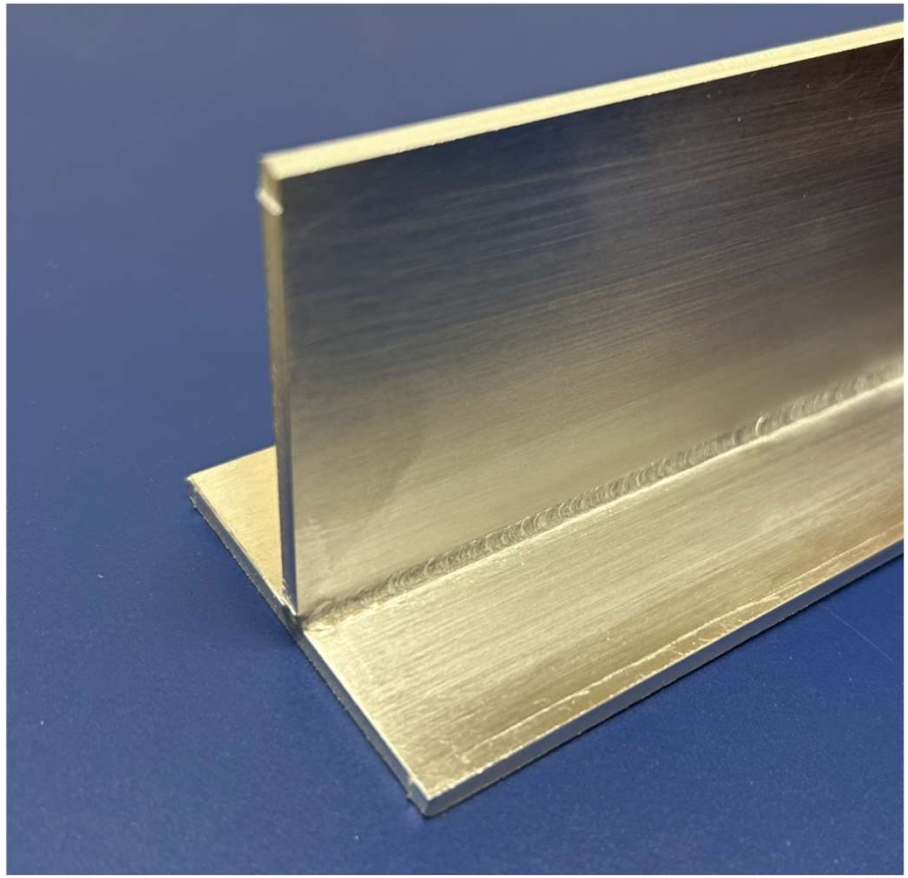


Third-party testing of final samples

- Fillet and groove weld samples were prepared for 0.063” and 0.125”
- 0.188” was omitted due to unresolved porosity and cracking issues
- Samples were evaluated by Mistras Group, LLC

Third-party testing of fillet samples

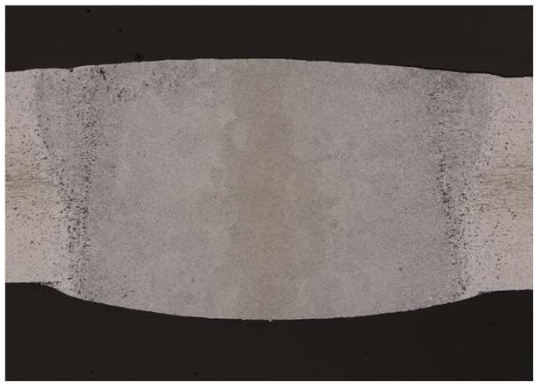
- Two 6-inch samples in each thickness were sent for liquid penetrant testing
- All samples met MIL-STD-2035 acceptance criteria

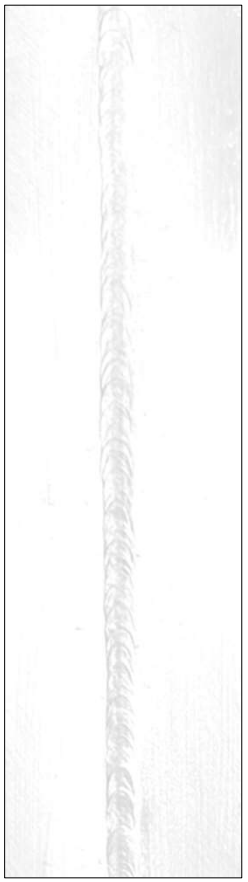


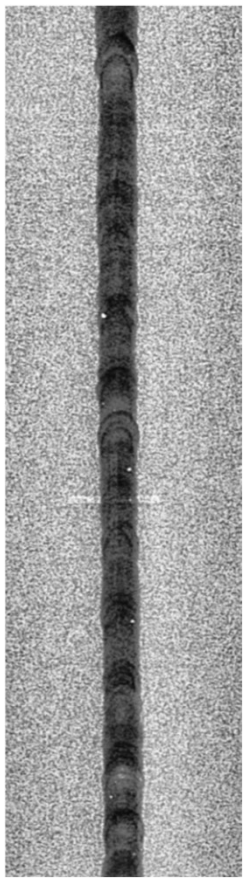
Third-party testing of groove weld samples

Two 6.5-inch samples in each thickness were sent for

- Liquid penetrant testing
- Radiographic testing
- Face and root bend testing
- Transverse tensile testing





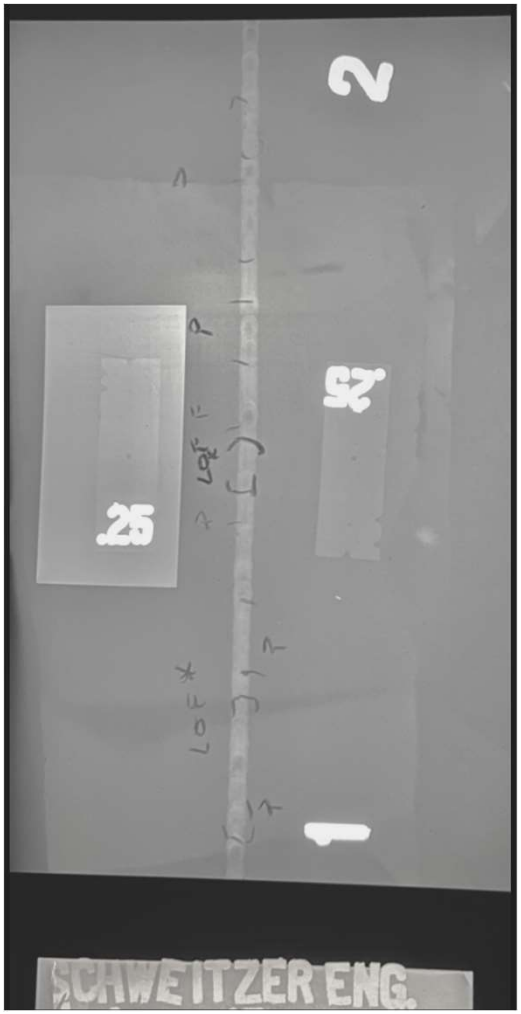


Groove weld – penetrant testing results

- 0.063-inch samples met MIL-STD-2035 acceptance criteria
- 0.125-inch samples met MIL-STD-2035 acceptance criteria

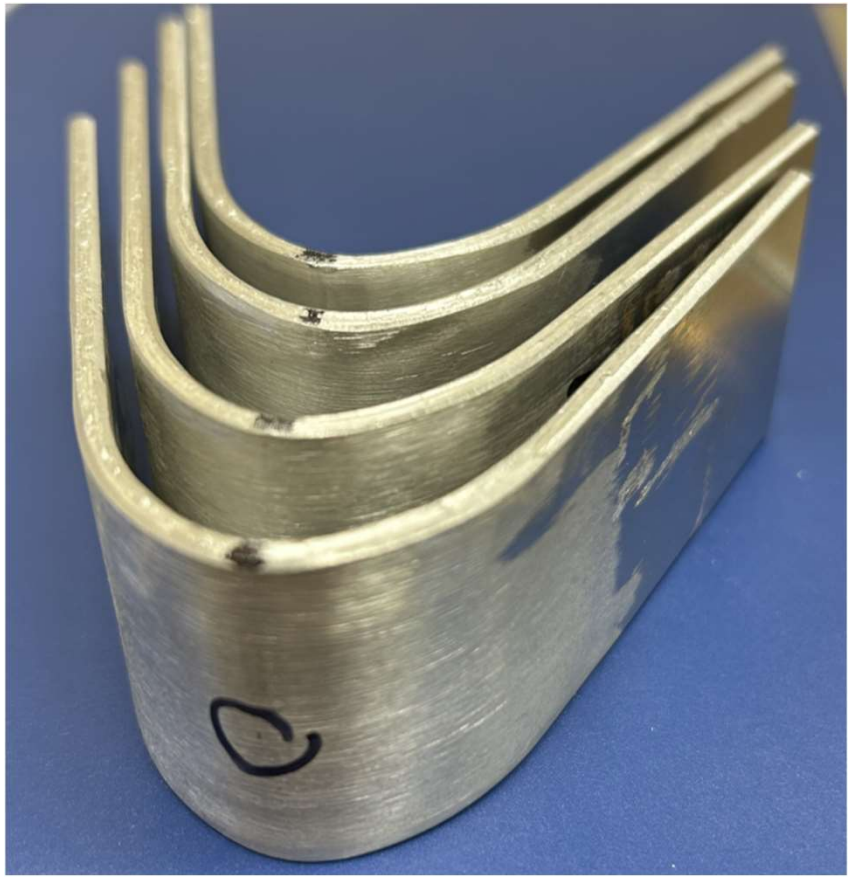
Groove weld – radiographic testing results

- 0.063-inch samples
  - One sample met acceptance criteria
  - One sample failed for an oversized pore
- 0.125-inch samples
  - One sample met acceptance criteria
  - One sample failed with indications of porosity and LOF



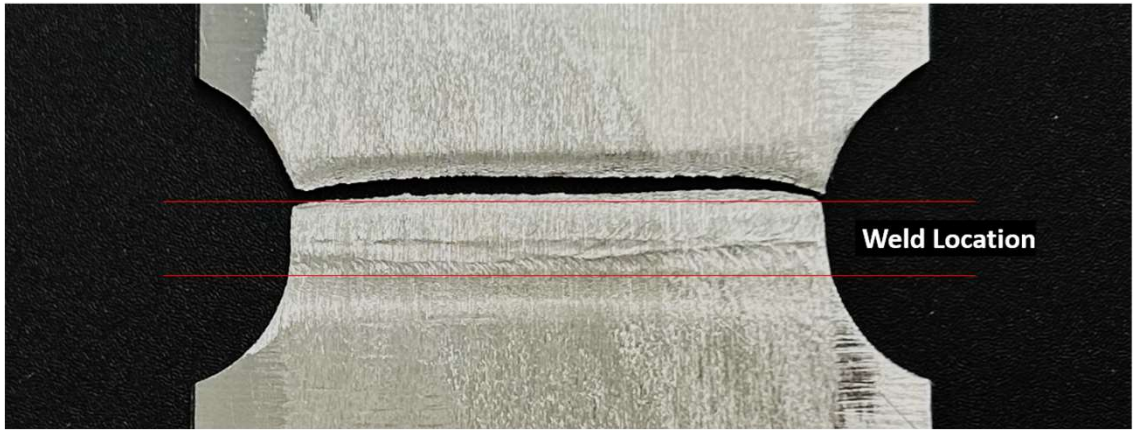
Groove weld – bend testing results

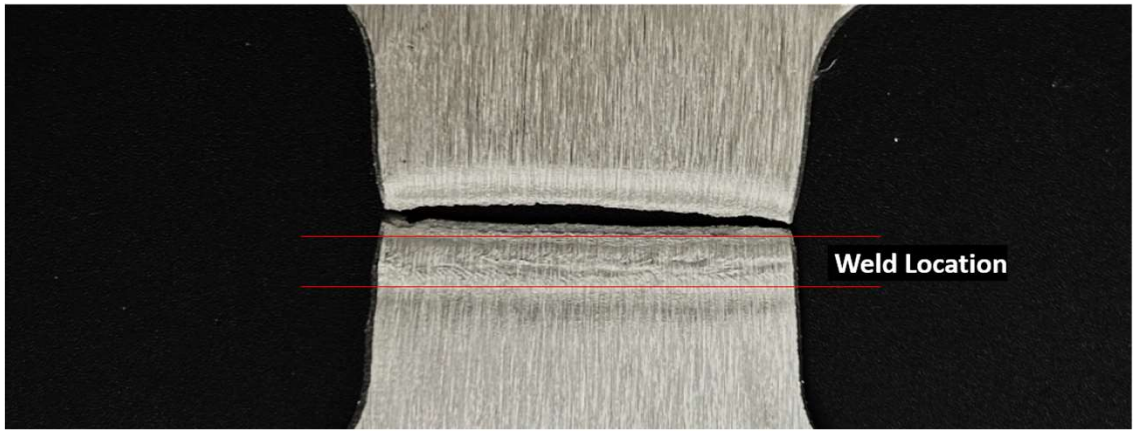
- 0.063-inch samples
  - No indications were on face or root bends
  - All samples met acceptance criteria
- 0.125-inch samples
  - One 1/16-inch indication was on root bend
  - All samples met acceptance criteria



Groove weld – tensile testing results

- 0.063” samples
  28,012 psi
- 0.125” samples
  26,279 psi
- QQ-A-250/8F 5052
  - H32 condition – 31,000 psi min
  - O condition – 25,000 psi min





Conclusions

- There is some operator dependence in the process
- Learning curve is significantly less than other processes
- Process development is required to produce crack-free fillet welds in 5052 aluminum
- Process development is also required to produce welds without excessive process porosity in 5052 aluminum
- Process is sensitive to small changes in setup and operation

Recommendations

- Experimentation with 4043 filler – may help fillet cracking
- Experimentation with more powerful handheld laser models
- Exploration of other base metals for potential quicker adoption of process
- Further refinement of parameters and techniques to consistently meet TP-248/278 requirements

Questions?

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