NSRP National Shipbuilding Research Program

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 plan overview

- Project plan and schedule creation
- IPG program baselines
- Initial air sampling
- 0.125-inch groove weld screening design of experiments (DOE)
- 0.125-inch groove weld optimizing DOE
- 0.125-inch fillet weld
- Follow-on air sampling



Project plan overview

- 0.063-inch groove weld
- 0.063-inch fillet weld
- 0.188-inch groove weld
- 0.188-inch fillet weld
- Final testing

Reports and presentations

"Evaluate progress" checkpoints



Laser welding system

IPG Lightweld XR Handheld Laser Welder

- 1500 W average/2500 W peak power fiber laser
- Manufacturer claims it can weld up to 0.250-inch 5XXX aluminum
- Included cleaning mode
- IPG Lightweld Wire Feeder

Operated by laser gun trigger (original model no longer available)



Safety hazards

- Laser radiation wavelength (1070 nm) is damaging to eyes and skin
- High beam energy/specular reflections can damage persons or property
- Welding fumes pose health risk (aluminum exposure)
- Sparks pose fire risk



Safety – engineering controls

- Dedicated laser welding area
- Door interlock switches kill beam if door is opened
- Windows covered with 0.063-inch aluminum sheet
- Fumex FA1 fume extractor
- Lightweld ground continuity system



Air sampling

• Conducted personal air sampling for aluminum

Two welding technicians wore pumps for testing over two days

Particle counter was used to verify ventilation effectiveness



Air sampling

• Conducted personal air sampling for aluminum

Welded groove and fillet welds in 0.125-inch and 0.188-inch material

Also operated laser in cleaning mode



Air sampling results

- Air samples were analyzed for aluminum by NIOSH Method 7303
- One sample was sent for transmission electron microscopy (TEM) to characterize nanoparticles created



Air sampling results

Results	OSHA PEL [*]	NIOSH REL**	ACGIH TLV***
<0.013 mg/m ³	15 mg/m ³	10 mg/m ³	1 mg/m ^{3 (R)*}
<0.016 mg/m ³	15 mg/m ³	10 mg/m ³	1 mg/m ^{3 (R)}
0.043 mg/m ³	15 mg/m ³	10 mg/m ³	1 mg/m ^{3 (R)}
 * – Permissible exposure limit ** – Recommended exposure limit 		*** – Threshold limit value(R) – Respirable fraction	e

(TEM analysis is awaiting results)

Safety – personal protective equipment

- Laser safety glasses
- Laser welding helmet
- Long sleeves
- Gloves
- P100 respirator (half-mask)



Q1 experiment progress

Experimental phases completed

- IPG program baselines
- Initial air sampling
- 0.125-inch groove weld screening DOE



Performed groove and fillet welds in 0.063-inch, 0.125-inch, and 0.188-inch thicknesses using built-in IPG programs

Weld prep process used

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



Initial evaluation

- Fillet welds metallographically evaluated for weld cracking
- Groove welds digital x-ray images captured for comparison







0.063-inch fillet sample





0.125-inch fillet sample





0.188-inch fillet sample



0.063-inch groove weld image



0.125-inch groove weld image



0.188-inch groove weld image

Screening DOE for 0.125-inch groove weld

- Conducted L8 Taguchi DOE with five replications
- Determined which weld parameters have significant effect on porosity
- Used digital x-ray and Image J analysis software to quantify porosity area



Screening DOE for 0.125-inch groove weld

- Varied seven parameters and two levels
 - Beam power
 - Wobble length
 - Wobble frequency
 - Wire speed
 - Gas pressure
 - Gas type
 - Welder/operator

Weld prep process

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



Screening DOE for 0.125-inch groove weld

- Parameters identified as producing main effects were
 - Beam power (*p*=0.16)
 - Wobble length (p=0.15)
 - Wobble frequency (*p*=0.15)

• Parameters determined to have minimal/no effect were

- Wire speed (*p*=0.91)
- Shielding gas pressure (p=0.95)
- Shielding gas type (p=1.00)
- Welder/operator (p=0.97)



Next steps

- Underway
 - Perform optimizing DOE focused on main effects identified in the screening DOE
 - Use RSM DOE
 - Use digital x-ray and Image J analysis software to quantify porosity area
- Upcoming
 - Evaluate overall project progress

Questions?

