Miniature Torch Speed Sensor Based Adaptive Manual Arc Welding

- Distribution: Participating Partners and US Shipbuilding and Repair Industry

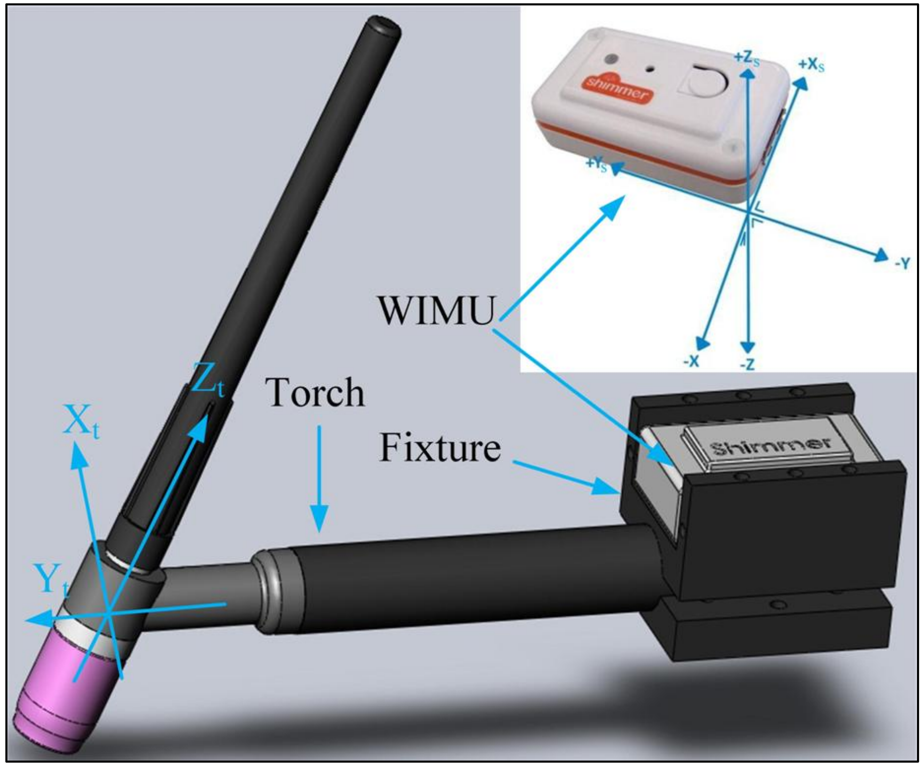
July 30, 2020 Welding Panel Virtual Meeting

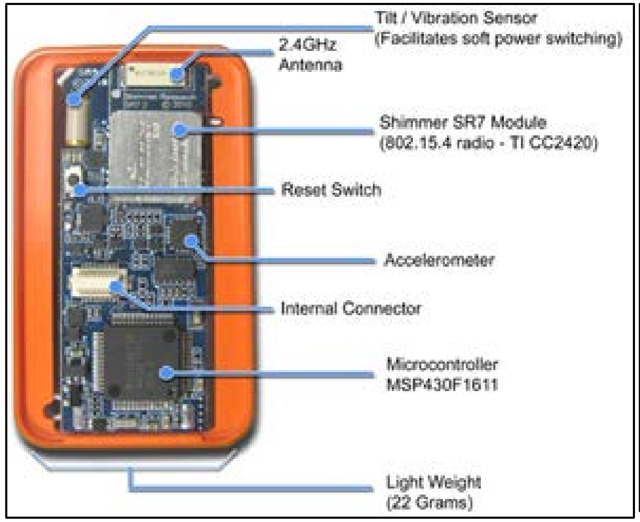
OUTLINE

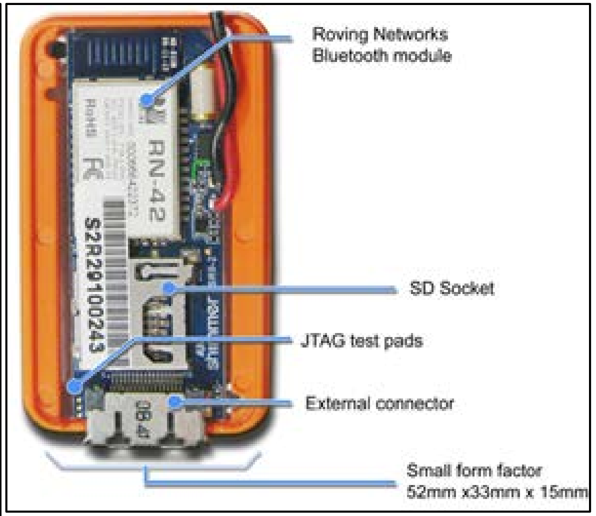
1. Previous Work
2. Team/Participating Partners and Objective
3. Progress
4. Next Actions
5. Benefits

Previous Work: IMU Based Method

Simmer Inertia Measurement Unit



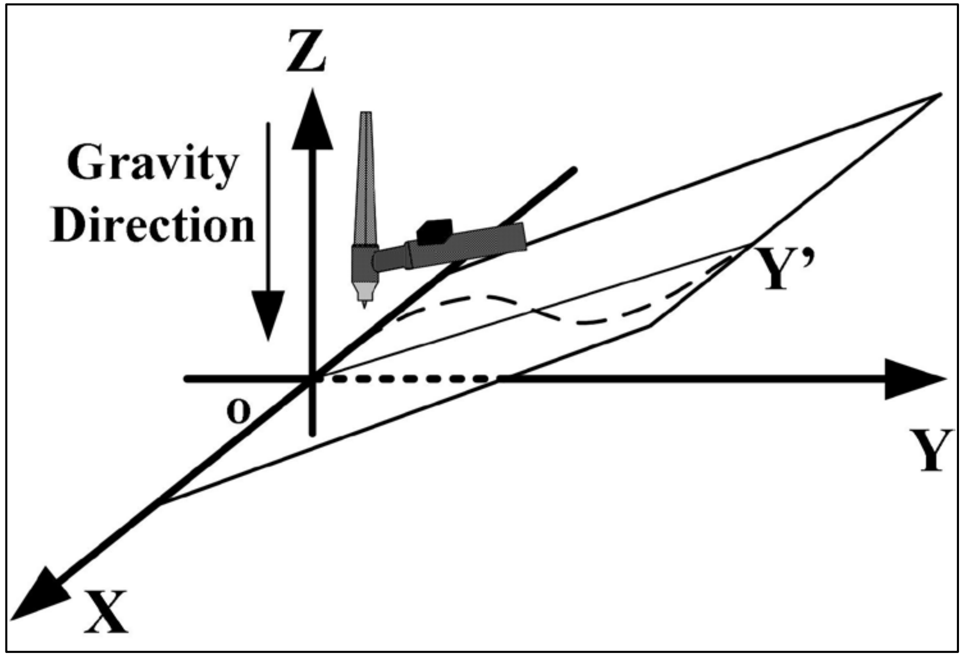


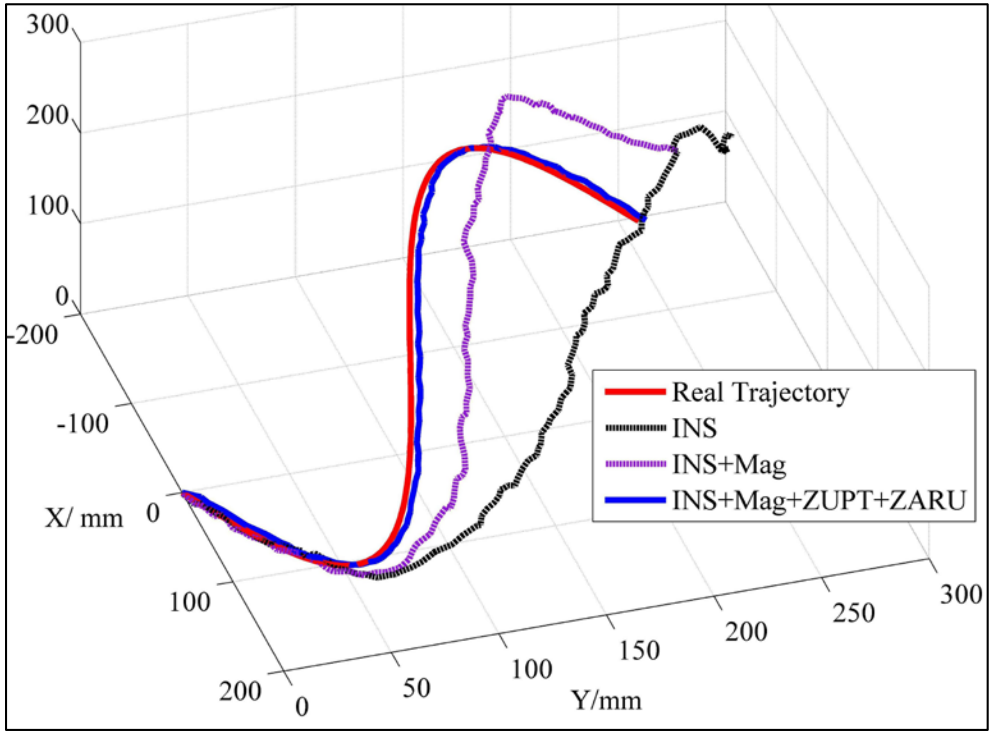


(1) tri-axial accelerometer (Freescale MMA7260Q); (2) tri-axial gyro sensor (InvenSense 500 series); (3) a magnetometer; (4) a microprocessor (MSP430F1611); (5) a Bluetooth unit.

Previous Work: Experiments and Results Analysis

- **Position experiment 2:** The torch is smoothly moved along the 3-D since curve.





The results of torch trajectory position estimation

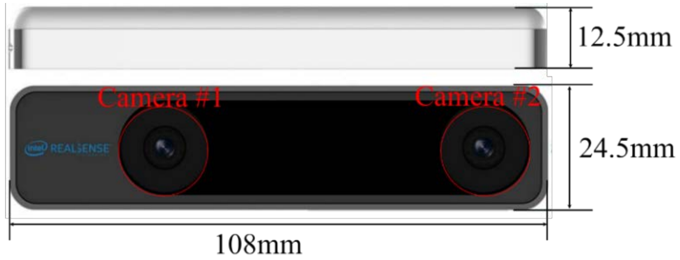
Estimation methods	Position error (% of TTD)
Kalman-based INS	> 25
INS+magnetometer	[7-16]
INS+magnetometer+ZUPT+ZARU	[0.5-1.7]

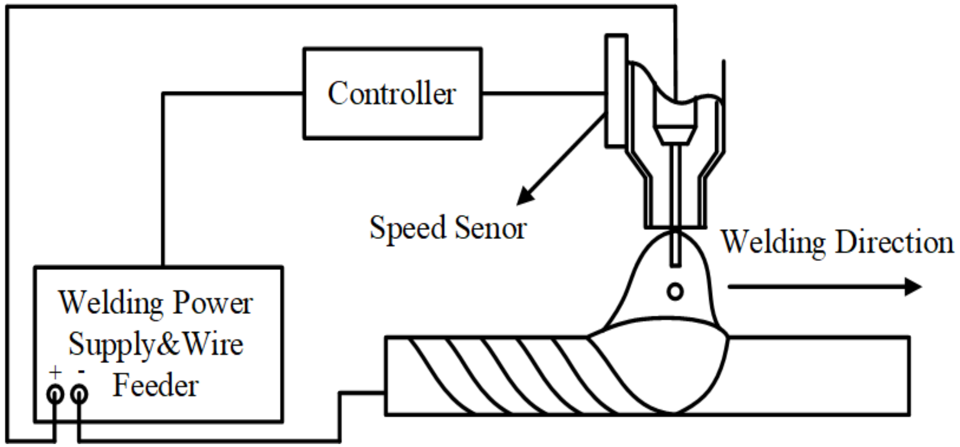
Measurement errors in Position Experiment 2

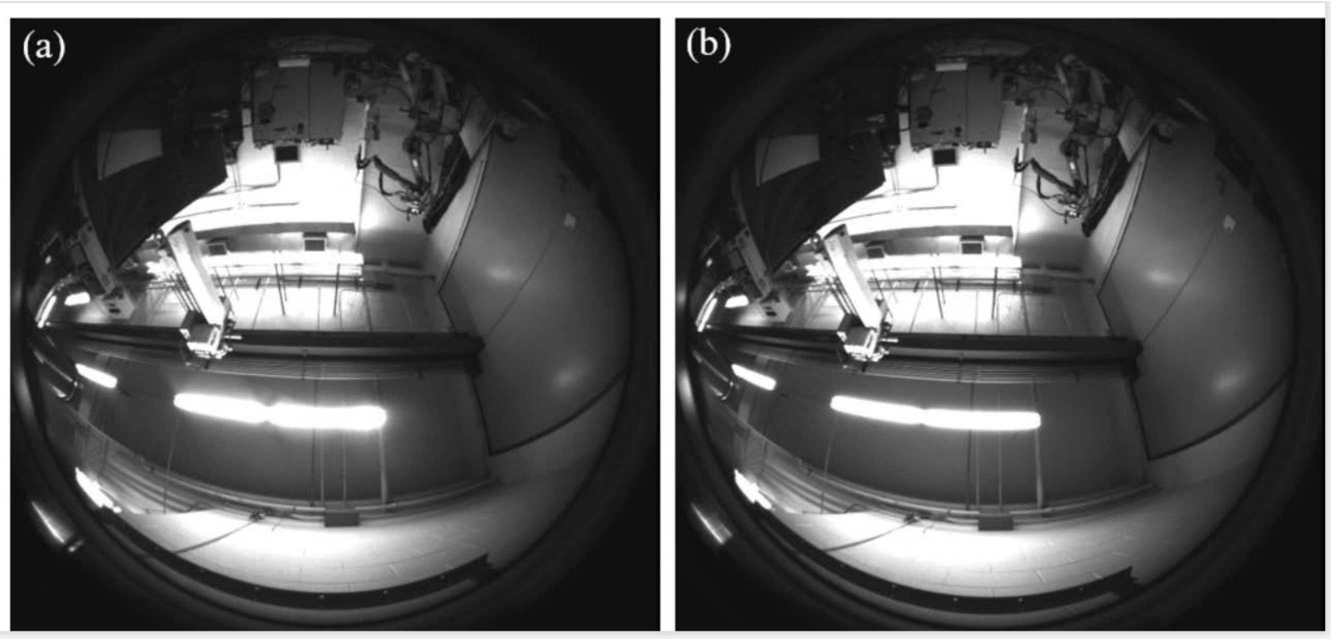
Team/Participating Partners of “Miniature Torch Speed Sensor Based Adaptive Manual Arc Welding”

- PI: YuMing Zhang - University of Kentucky
- Shipyard Application: Joe Caron - Huntington Ingalls Industries (Ingalls)
- Equipment and Commercialization Path: Todd Holverson - Miller Electric Company
- TPC: Yu-Ping Yang - Huntington Ingalls Industries (Ingalls)

Objective: IMU+Vision



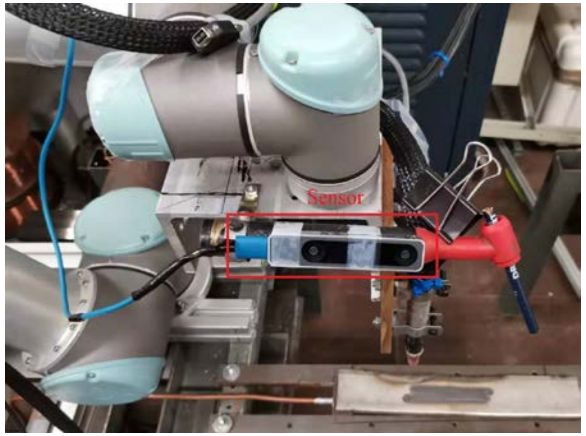


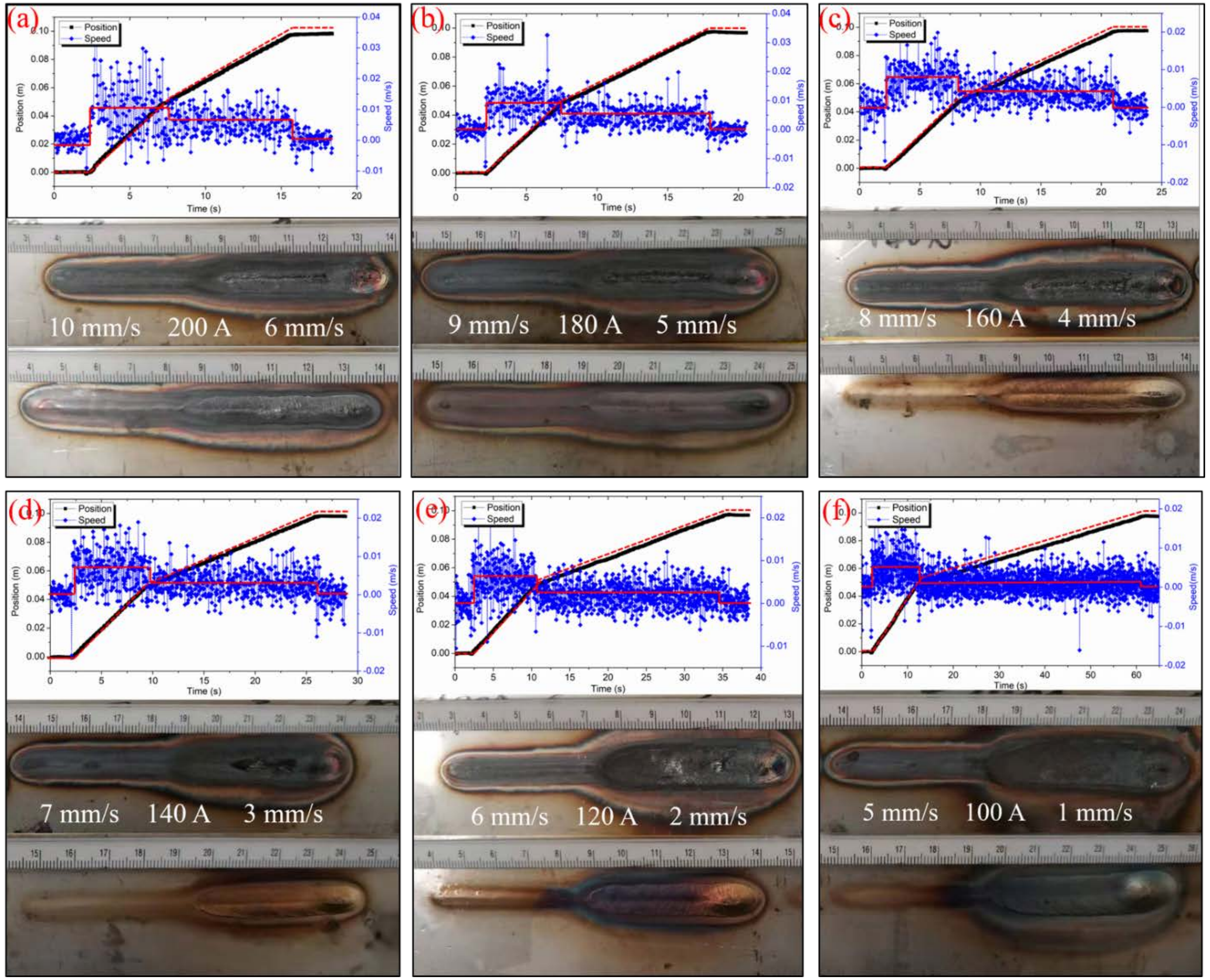


Progress: Summary

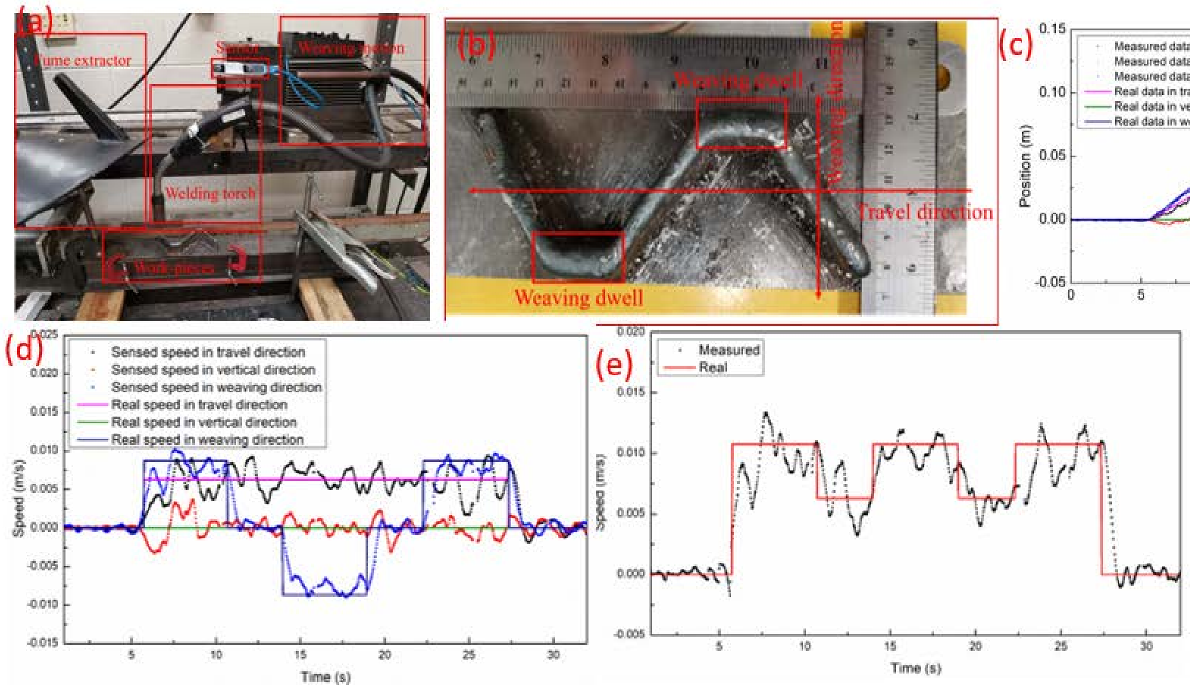
Speed Monitoring with Verified Accuracy during Various Welding/Arcing Conditions & Adaptive Welding

Progress: Robotic Verification - GTAW





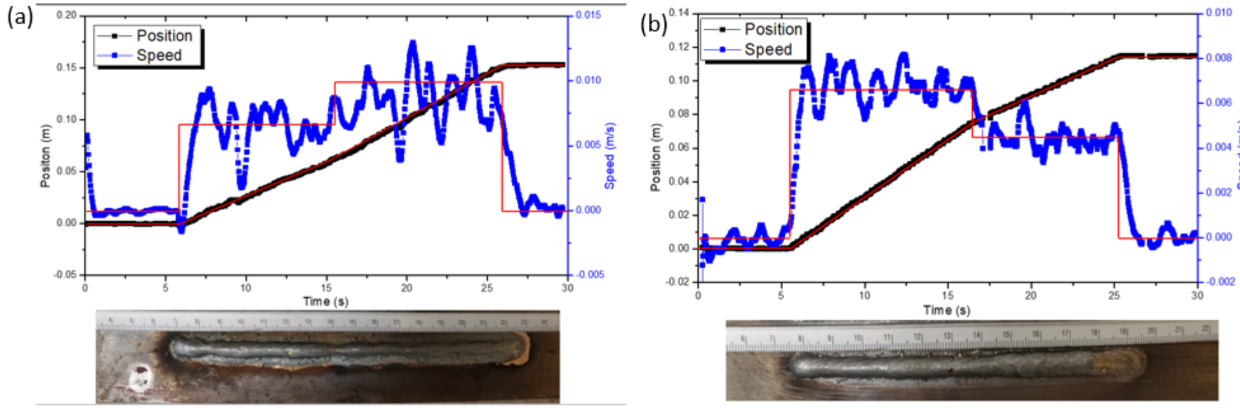
Progress: GMAW



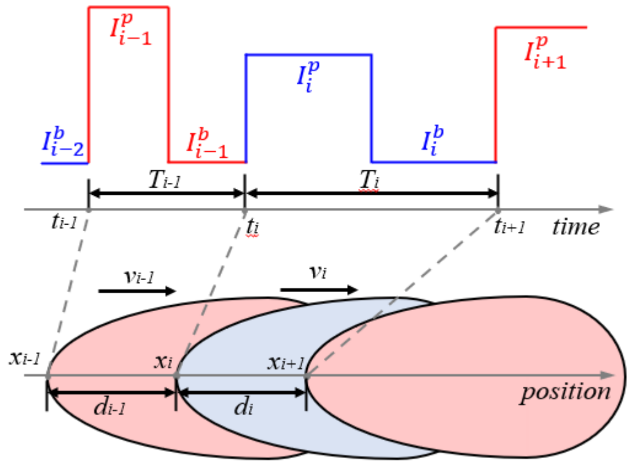
(f)

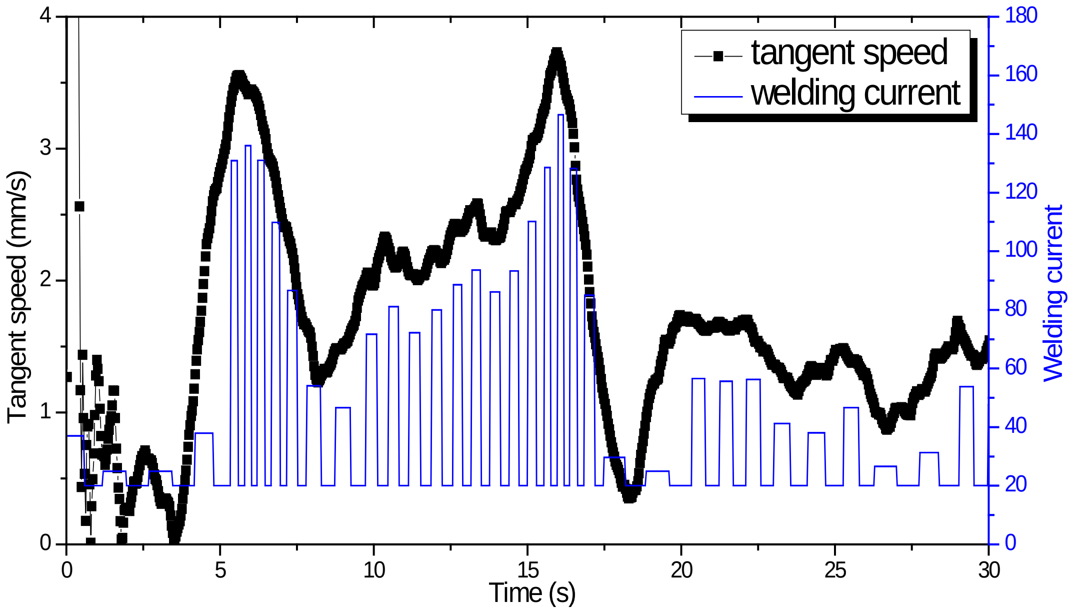
Speed sensing error

Direction	RMSE (mm/s)
Travel	1.86
Vertical	1.10
Weaving	2.08
Main	2.13



Progress: Manual Pulsed GTAW



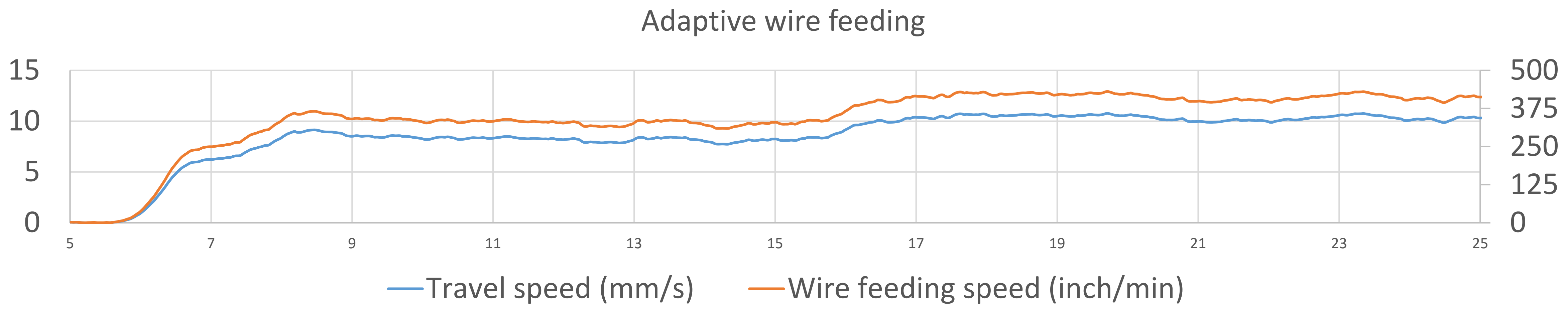


Progress: Semi-automatic GMAW

Adaptive wire feeding:
Wire feeding speed (WFS) is proportional to travel speed (TS) to maintain constant mass/heat input
Our strategy: WFS (IPM) = 40 * TS(mm/s), welding voltage: 23V

Hardware:
(1) Intel RealSense T265 ---- position/pose tracking
(2) PC ---- TS computation, WFS computation
(3) Analogy interface ---- communication with welding power supply
(4) Welding power supply ---- Miller auto-continuum 500
(5) Bug-O tractor ---- welding torch movement

Step experiment: speed increases suddenly



Progress: Semi-automatic GMAW

Welding results:

With adaptive wire feeding

Without adaptive wire feeding

Without adaptive wire feeding, weld bead is thinner than before due to increased travel speed.
The weld bead is consistent after adaptive wire feeding.

Status of the Project:

Current Project:

Finished: Adaptive Wire Feed Speed Control System

Realized by a control system includes (1) a power source which can receive command in real-time from the computer (that processes the sensor data to obtain the travel speed) to adjust the feed speed, (2) the monitoring system, (3) a computer system with data acquisition system to read data from the monitoring system and send command signals to the power source, and (4) control algorithm that coordinate the actions and determine the adjustment from the wire feed speed per the torch speed.

To Finished: Prepare the System for Semi-Automatic FCAW Trial and Demonstration at Ingalls

Beyond Current Project:

Demonstrate to shipyards and Miller for Possible Commercialization: FCAW, GMAW, GTAW, Pipe (Making Welds Like Orbital Systems and Pipe Welder Training)

Benefits:

1. Make quality welds with less training
2. Automated detection of weld length and position
3. Records for locations of possible defects (for example lack of penetration)
4. Assured weld size and heat input; records of heat inputs for different welds/weld segments
5. Directions for welder improvements/trainings

Question?

Optimized Weld Records

Project Lead Organization: TruQC
Project Team Members: EWI, Vigor

Concept/Idea

Problem:

- Welding processes require input from multiple individuals, documents and specifications, making proper management a challenge
- Quality Assurance (QA) procedures can be expensive, inefficient, and difficult to administer

Proposed Solution:

- TruQC, a commercial off the shelf (COTS) software, will be configured to manage welding requirements and records
- TruQC will be a single access point to the data needed to complete and document welds for engineers, inspectors, supervisors and welders

Benefits/Justification

- More access to welding requirements and records will improve efficiency of planning, process improvement, and troubleshooting
- Expedite decision-making, reducing analysis costs and associated downtime
- Automated document organization for easier audits
- Consolidates data for re-work tracking with weld specific information
- Minimize or eliminate delays associated with adjudication of out of spec items
- Reduce inspection costs
- Eliminate costs incurred to re-create history of assessments
- Increase transparency of inspection to the welding process

Project Approach

High Level Statement of Work:

- TruQC will develop a weld requirement and record specific solution that connects resources and documents
- TruQC will work with EWI and Vigor to test and introduce the solution to shipyard personnel

Metrics of Success:

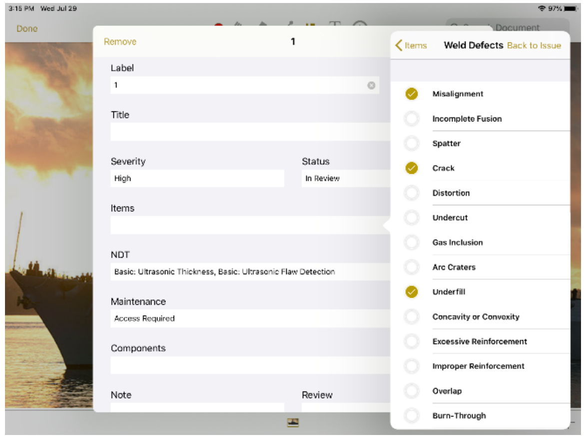
- TruQC solution for creating weld requirement documents, collecting weld record data and limited deployment to shipyard personnel for buy-in development
- Compare digitalized weld lifecycle process using TruQC to the traditional paper method previously used

Cost/Images/Relevant Information

Project Estimated Cost:

$150,000

- TruQC will work with partner shipyards to create and administer a survey to shipyard personnel to examine current weld requirements, record management and NDT requirements with plans to grow this into an RA project



Improved Toughness of Hybrid Laser Arc Welding

Project Lead Organization: Ingalls Shipbuilding
Project Team members: Edison Welding Institute

Concept/Idea

- **Issue:** Current hybrid laser arc welding (HLAW) approvals are limited to internal decks and bulkheads and superstructure. Shell plating and other areas exposed to the lowest service temperature are restricted due to poor toughness at low temperatures.

- **Proposed Solution(s):** *):* Investigate increased preheats and alternate filler materials to determine if impact properties can be increased when compared to current welding procedure requirements.

Benefits/Justification

Benefits of the project

- Further understanding of the HLAW process and how cooling rates and filler material effect toughness properties.
- Justification for additional dynamic impact testing that would to be performed at Naval Surface Warfare Center, Carderock and under direction from NAVSEA 05.

Project Approach

High level statement of work

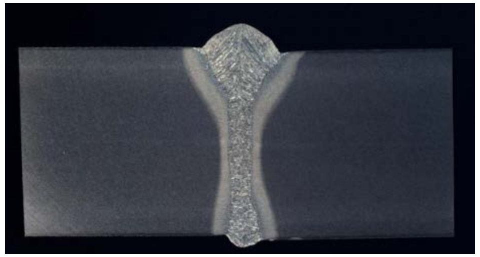
- Compare HLAW weldments using increased preheats to current welding process.
- Compare HLAW weldments using alternate filler materials to current welding process.

Metric(s) of Success

- Perform standard and side grooved Chapry V notch testing, as well as micro hardness, to determine if toughness has been improved with increased preheat temperatures and/or alternate filler material.

Cost/Images/Relevant Information

- **Project Duration:** 12 Months
- **Project Cost**: $150,000



Effects of Raw Plate Distortion on Seaming of Panels and Real Time Distortion Measurements During Panel Fabrication

Project Lead Organization: Ingalls Shipbuilding
Project Team members: TBD

Concept/Idea

- **Issue:** Incoming plate quality, even when in accordance with purchasing specifications, has shown distortion greater than what current mechanized systems are capable of handling. This has also decreased the ability to maximize downstream distortion reduction efforts.
- **Proposed Solution(s):** *):* Determine distortion limits for raw material that will ensure success during seaming applications using mechanized welding processes. Measure distortion throughout panel fabrication to determine areas where improved techniques, material handling, or welding sequences can limit or reduce distortion.

Benefits/Justification

Benefits of the project

- Establish standards and tolerances for incoming plate quality
- Determine most effective weld sequence for limiting distortion when welding structural members to panels

Project Approach

High level statement of work

- Measure as received plate via laser scanning to produce 3D model.
- Measure panels after seaming via laser scanning to produce 3D model, as well as document any areas that require rework due to distortion in as received material.
  - Compare as welded condition to as received condition to create plate flatness standard.
- Measure panels before and after welding of longitudinal and transverse structure using multiple sequences to determine most effective for reducing distortion.

Cost/Images/Relevant Information

- **Project Duration:** 12 Months
- **Project Cost**: $150,000

EWI 2021 White Papers for NSRP Welding Panel

DENNIS HARWIG, ***Senior Technical Leader***

- Arc Welding & DED Processes

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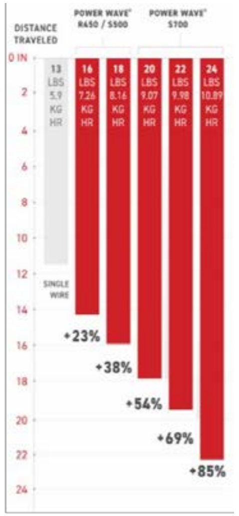
Presentation Objectives

- Provide short overview on two FY21 whitepapers for Welding Panel consideration:
  - Next Generation Double Electrode GMAW Process for Precision Fillet Welding
  - Portable Single-Pass Buried Arc Welding of Steel Plate During Ship Erection

Background – NSRP FY19 Project - High Deposition Robotic Arc Additive Mfg. Process Development

- Double Electrode GMAW
  - Offers 200% to 300% improvement compared to single wire GMAW for welding applications
- Compared Lincoln's Tandem, Twin and Hot Wire Tandem systems for DED

- Twin-wire GMAW solution (TW-GMAW)
- Designed for semi-automatic and automatic applications
- Deposition rates above 18-lbs./hr. (24+ lbs./hr. robotically)
- Ease-of-use (one power supply / feeder)
- Not direction dependent

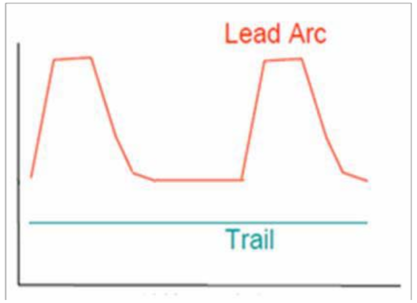


- Two-wire GMAW solution (Tandem P-P)
- Designed for automatic applications
- Deposition rates of 16- to 40-lbs./hr.
- Complex system (two power supplies / feeders)
- Direction dependent

Conventional Synchronized Tandem MIG

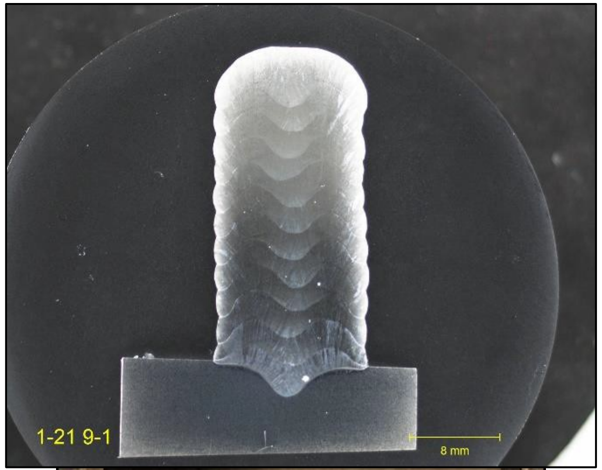
180° out of phase

- Two-wire GMAW solution with reduced heat input up to 40% (Tandem P-HW)
- Designed for automatic applications
- Deposition rates of 16- to 40-lbs./hr.
- Complex system (two power supplies / feeders)
- Direction dependent

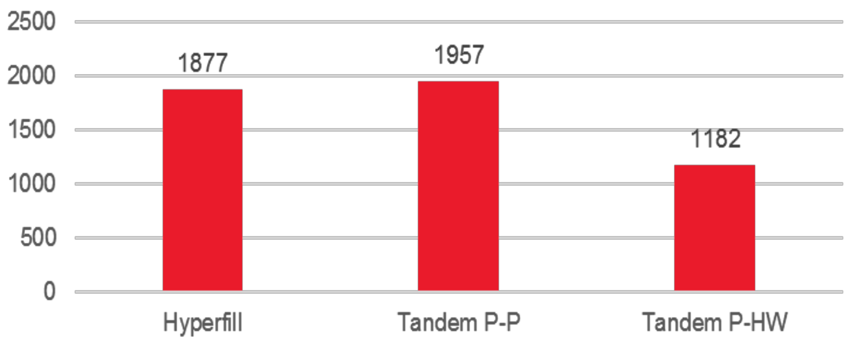


Double Electrode GMA Process Comparisons - Mini-build

Process	Maximum Deposition Rate Achieved (lbs./hr.)	Heat Input (kJ/lb.) at 20-lbs./hr. Dep. Rate	CTWD Sensitive?	Ease-of-Use?	Direction Dependent?
HyperFill™	25	1877	No	Yes	No
Tandem P-P	30	1957	Yes	No	Yes
Tandem P-HW	30	1182	Yes	No	Yes



Heat Input (kJ/lb.) at
20-lbs./hr. Deposition. Rate



Twin Wire (Hyperfill) was selected based on best combination of productivity & quality on mini-wall tests

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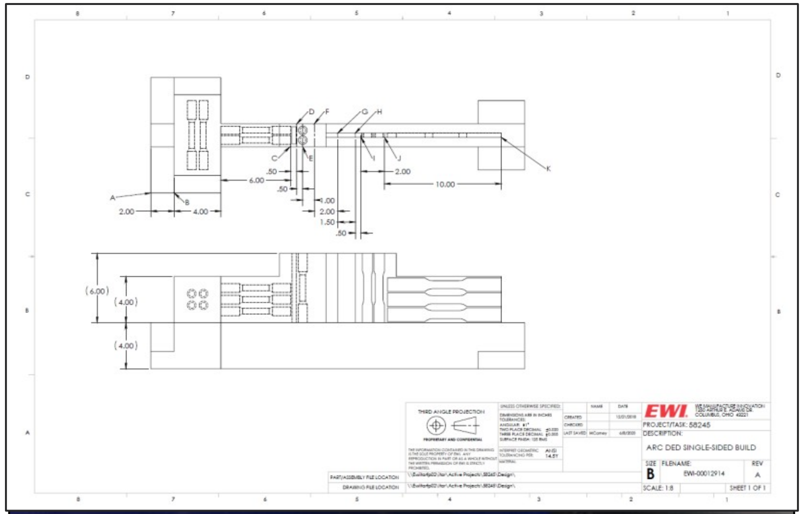
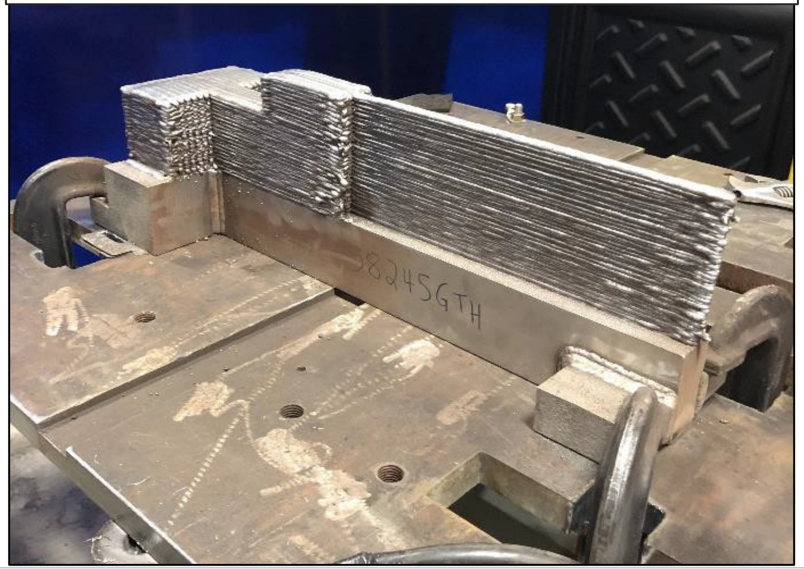
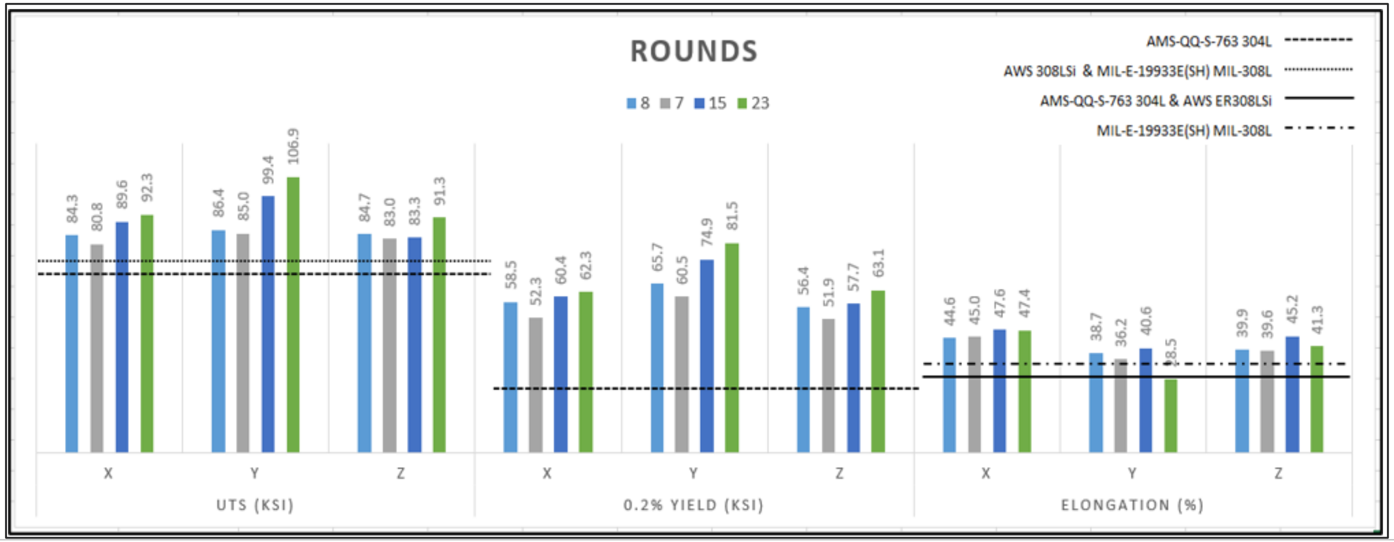
Twin Wire GMA-P DED SQB Performance





	Deposition (lb/hr)	WFS (IPM)	# Wire	TS (IPM)	Wire Dia (in)	WFS/TS	Deposition Increase Over Max GMAW-P (%)
GMA-P	8.41	305	1	20	0.045	15.25	
GMA-P	6.89	250	1	8	0.045	31.25	
TW-GMA	15.25	350	2	20	0.04	35	181%
TW-GMA	22.88	525	2	25	0.04	42	272%



FY21 NSRP Panel Project - Next Generation Double Electrode GMAW Process for Precision Fillet Welding

Objectives:

- Evaluate and benchmark advanced double electrode GMAW processes and consumables for high speed deposition of 4 mm horizontal fillet welds
- Survey industry, screen candidate processes, and select preferred process for feasibility testing.
  - Twin (i.e Lincoln Hyperfill),
  - Hot wire tandem (Lincoln),
  - Tandem (Cloos),
  - Adjustable configuration tandem (D&F Specialty Torch), and
  - Advanced consumables for tandem (advanced metal core electrodes for high speed performance),
- Down-select and develop ARCWISE operational windows and bead shape maps for up to three process combinations.
- Provide technology transfer and demonstration workshop upon project completion.

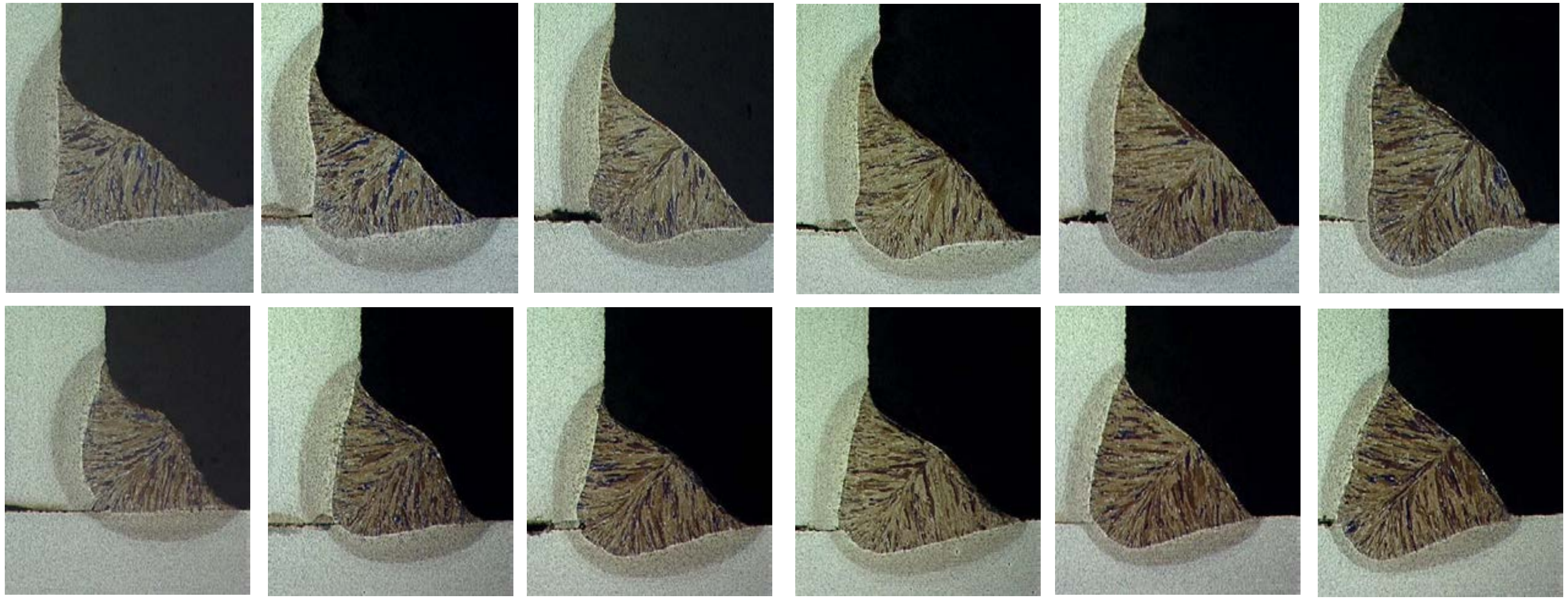
ARCWISE Background – FY20 Tandem - GMAW Bead Map 5 mm Horizontal Fillet Welds

CTWD = 19 mm

WFS/TS = 9.96 (1.2 mm electrode)

WFS_T/WFS_L = .5

1.3 mm (.052 in) ER70S-6 Electrode
90% Ar/10% CO_2
Pulse mode

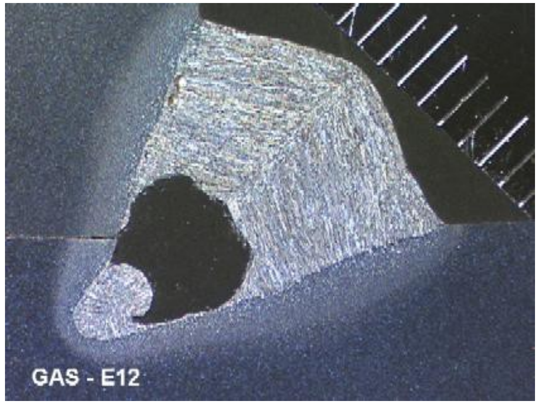


3 mm Arc Length

1 mm Arc Length

0.8 m/min (30 in/min)	1.0 m/min (40 in/min)	1.3 m/min (50 in/min)	1.5 m/min (60 in/min)	1.8 m/min (70 in/min)	2.0 m/min (80 in/min)

Optimum



Single electrode - plasma-jet induced porosity at high I

ARCWISE

- Systematic parameter development method for target applications
- Arc length – productivity - weld quality
- Develops functional relationships between:
  - V - I
  - V - WFS
  - I - WFS
  - HI - Productivity (DR or TS)
- Foundation for knowledge-based procedure development

FY21 NSRP Panel Project - Next Generation Double Electrode GMAW Process for Precision Fillet Welding

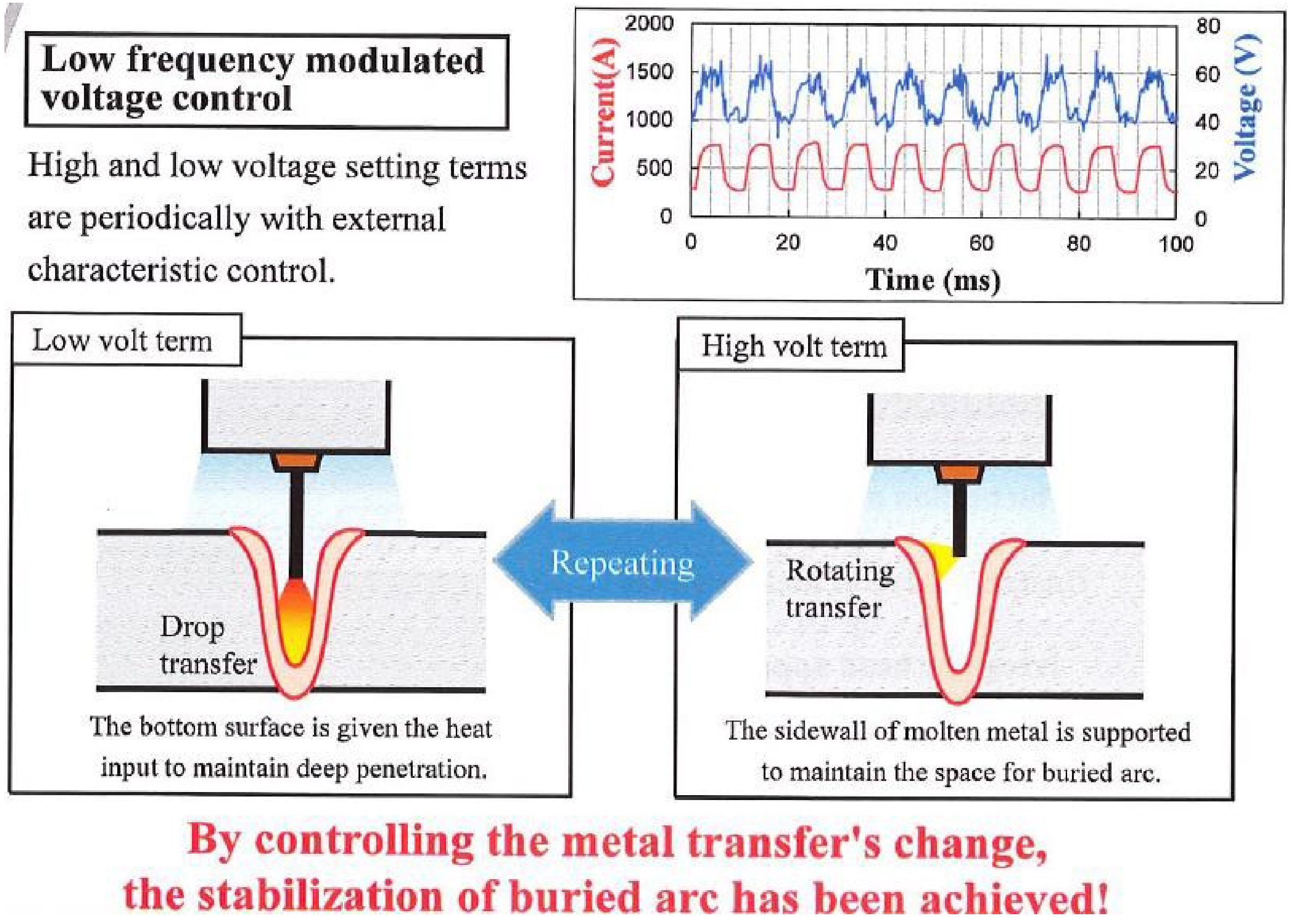
- Benefits:
  - Provide 2 to 3X the productivity of single electrode GMAW
  - Reduce heat inputs and distortion.
  - Reduce overwelding of “thin” high strength steel structure.
    - Very susceptible to distortion from over-welding.
      - Distortion correction costs = 30% of the ship structure fabrication costs based on a prior study.
  - Precision fillet welding
    - Reduce distortion, and
    - Support neat construction fabrication methods,

Background - FY20 NSRP Project – High Penetration Dynamic Buried Arc Welding

- OTC Daihen buried arc GMAW-P system
  - Welbee DPS power sources (2)
    - Programs designed for 0.052-in. Ø and 0.062-in. Ø steel wire, CO_2 shielding gas, and steel base material
  - Servo wire feed controllers (2) (DFC-PLAC)
  - Push wire feeder (DF-PS-E)
  - Pull wire feeder (DF-PL-E)
  - Torch, 2.5-m (L-10635)
- Developed procedures for 3/8 and ½ steel butt joints

Buried Arc GMAW-P for Erection & Small Panel Butts

- Process Characteristics
  - High Current Welding Power Source (1000 Amps)
  - High Speed Wire Feeder (70m/min)
    - 1.3 mm (0.052”) and 1.6 mm (0.062”) Electrodes
  - Advanced Water Cooled Torch
  - Advanced Arc Stabilization Technology for Buried Arc
    - Dual metal transfer - axial spray and rotating spray metal transfer control



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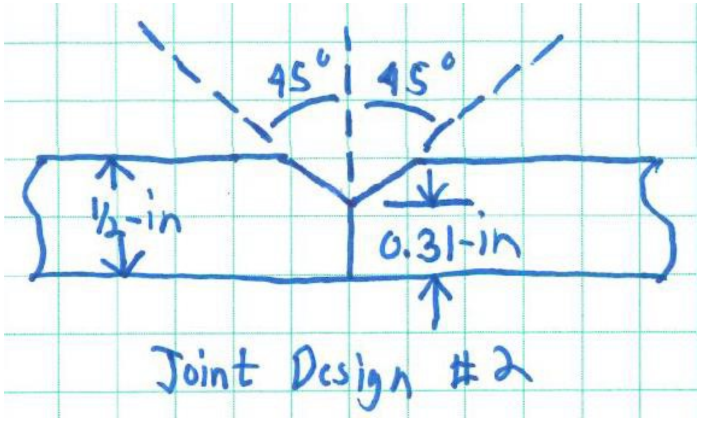
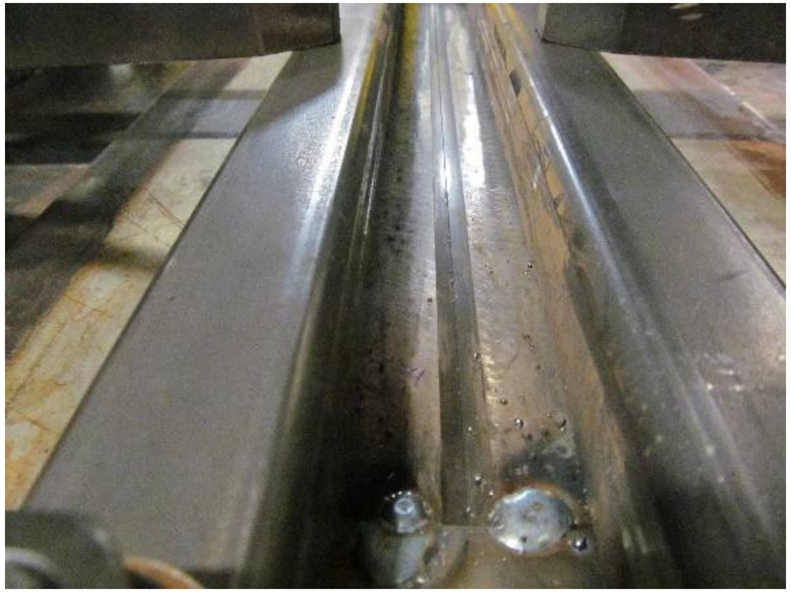
Buried Arc Example - 1/2-in. DH36 Plate

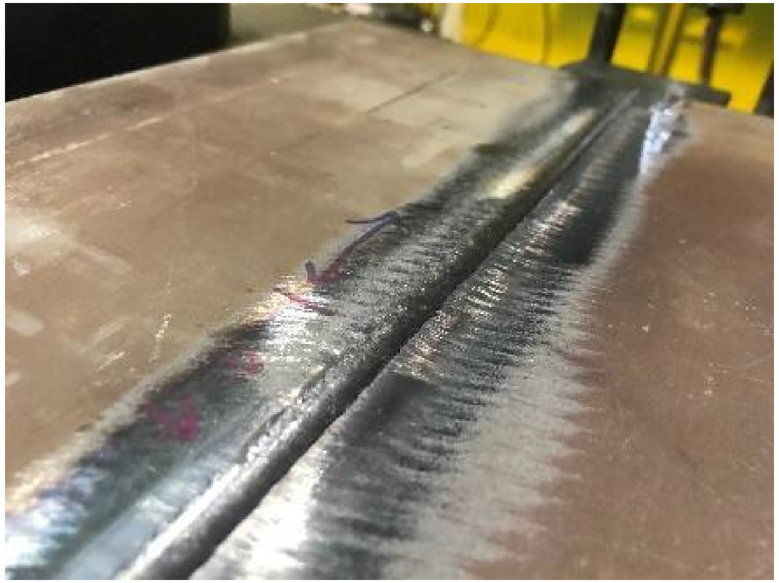
- Application 1
  - ½-in. DH36 plate
  - Evaluate NDE and mechanical testing requirements
- Procedure Test Conditions
  - Butt-joint in ½-in. thick DH36 steel plate
    - 0.31-in. root face, 90° included angle
    - 525 Amps, 18 ipm TS, 75KJ/inch
  - ER70S-G wire, 1/16-in. Ø; CO_2 Shielding Gas
  - Backing
    - Ceramic backing (W49)
    - Copper backing bar (W50)
  - No gap
- Evaluated
  - NDE: VT, PT, MT, RT, UT
  - Mechanical testing (tensiles, bends, charpys)

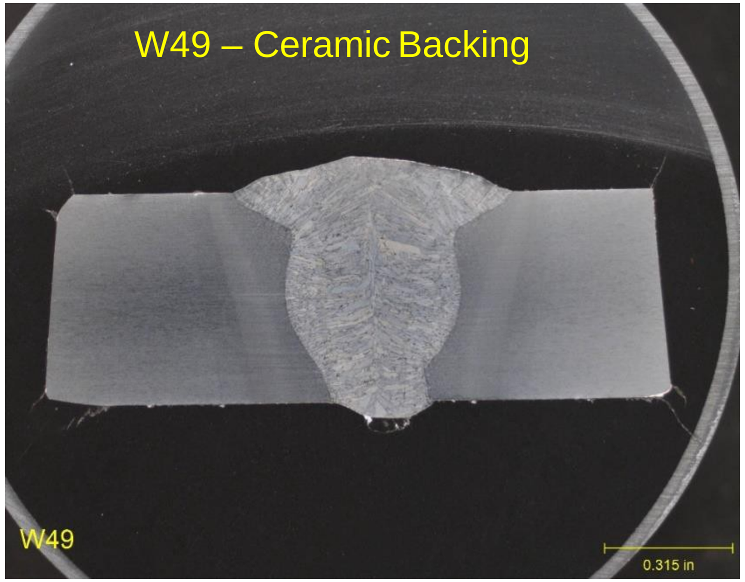


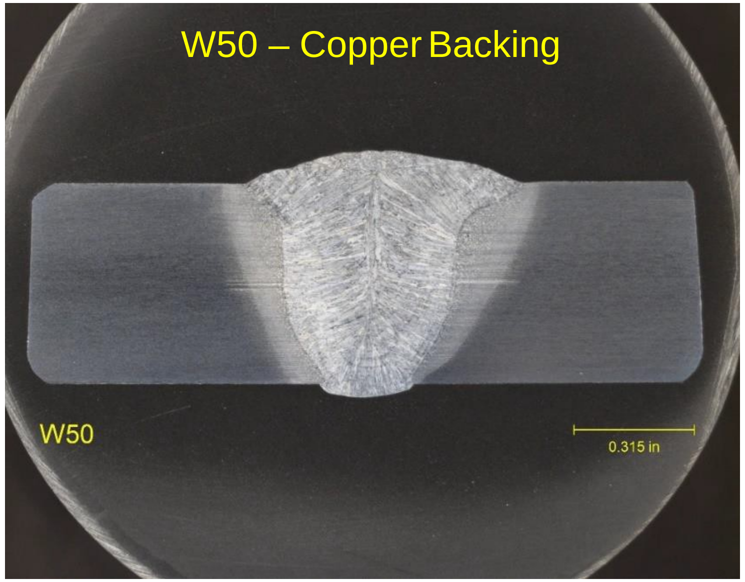


Tests Results with Different Backing

- Met sections were removed from steady state area
  - Examination at 25X in unetched and etched conditions - defect free
- Ceramic backing resulted in a smoother toe
- Weld mechanical properties met requirements
- Significant potential for single pass butts and fillets up to 19-mm (0.75-inch)







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FY21 NSRP Panel Project - Portable Single-Pass Buried Arc Welding of Steel Plate During Ship Erection

- Goals:
  - Develop single-sided, single-pass, full penetration butt joint welding procedures for erection joints using the GMAW-B process,
  - Reduce distortion and total weld cycle time, and
  - Reduce plate preparation and post-weld straightening costs

- Objectives:
  - Develop portable mechanized GMAW-B methods for candidate application(s),
  - Demonstrate that the developed GMAW-B methods can meet identified ABS and NAVSEA procedure qualification test requirements, and
  - Support implementation at a participating shipyard.

FY21 NSRP Panel Project - Portable Single-Pass Buried Arc Welding of Steel Plate During Ship Erection

- Benefits:
  - Reduce the cost and time associated with welding vessel erection joints up to ¾" thick:
    - Reduce the number of passes
    - Reduce arc-on-time by up to 80%
  - Reduce plate preparation and post-weld straightening costs:
    - Simplify joint prep
    - Reduce distortion via single versus multiple passes
      - Significantly less total heat input
  - Eliminate slag removal and the risk of inclusions.

Questions?

Thank you for your time.

DENNIS HARWIG, *Senior Technical Leader*
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