National Shipbuilding Research
Welding Technology Panel Meeting
April 8-9, 2014

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Welding Discussion

• Agenda

• Improved Welder Productivity

• Robotic Welding of Part Family and Interim Product Assemblies

• Robotic Welding of Major Assemblies
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Improved Welder Productivity
Original Concept

- Wouldn’t it be neat if we could develop a “smart welder system” that would eliminate Wrong Weld Wire occurrences?  P. Cournoyer
  - The system would perform all of the necessary checks performed today, and make a go, no-go decision
    - GO = Machine on, work begins
    - NO-GO = Machine shut down.  (WWW no longer possible)

- Quad Chart Created for ManTech Consideration
- Funding Received
- Kick-off Meeting Held May 2012
- Information collected from Welding Suppliers at FabTech
  - Power Supplies were being networked
- Need for thorough Market Survey was apparent
Challenges / Objective

• Challenges
  • Wrong Weld Wire occurrences drove start up time
    – Self imposed strict regulations
  • Current welder shift startup tasks are very time consuming
    – Receiving assigned work/Pre-job briefing
    – Checking out weld wire from the tool crib
    – Verifying qualifications and work pieces
    – Pre-job checklist

• Objective
  • Improved welder startup process
    – Reducing the time required to strike an arc
  • Investigate commercially available technology
    – Use software to automate checks and determine Go/No-Go decision
    – Real time monitoring of productivity
    – Incorporate additional benefits of software

“Allow welder to show up and weld like a surgeon arriving at an operating room.” - Ops. Management
Objective (Continued)

- Develop and pilot a “Smart Welder” system that considers:
  - Electronic work assignment (supervision to tradesmen)
  - Electronic retrieval of relevant work package information
  - Electronic delivery of weld procedure
  - Correct weld wire verification
  - Welder qualification validation

- Identify “Just Do-It” Process Improvements
- Share improvements with other Navy shipyards
Current Process

- Shadowing of several welders
  - Determine what is required in the current start up process
  - Amount of time consumed by current process
    - Average start up time was established
  - Multiple assignments each day
    - Average additional starts of 3 per day
- Use process inputs to develop system requirements for market survey
Market Survey

- ARL team members researched commercially available products
  - Each product’s features were evaluated and compared to the others
  - Which product could fulfill the requirements of the project?
- Live demonstration of two products after initial down select
- Lincoln Electric was selected as the preferred supplier
On Site Demonstration

• Lincoln Electric on site demonstration at Quonset Point
  • 3rd Generation Power Supply
    – Powerwave s500
    – Software suite of tools: CheckPoint, Weld Sequencer, & WeldScore
  • 100+ Electric Boat Quonset Point and Groton personnel
    – Management, Engineering, Supervision, and Trades
    – Hands on demonstration and explanation of the commercially available system
Selected System

- Lincoln Electric Cots Software
  - Suite of Tools:
    - **CheckPoint™** Production Monitoring Tool
      - Power supply and weld data collection
      - Control of shop floor assets (wire feeders and power supplies)
    - **Weld Sequencer** Sequence Assembly Tool
      - Control individual steps of weld sequence
      - Use in Go/No-Go decision
    - **WeldScore™** Weld Process Monitoring Tool
      - Additional benefit of software
        » Early weld defect detection
      - Next generation power supplies
Where Are We Now?

- 8 Lincoln Powerwave 455’s have been back-fit with network cards and connected to the EB network via ethernet cables
  - Phase I will provide real time productivity metrics
- SmartWelder process has been prototyped at ARL in a lab environment
  - Successfully provided a go, or no go decision
- Obtaining necessary hardware for Phase II prototype
  - Limited SmartWelder trial in shipyard environment
- Ready to start a “Green Welder” prototype that will train new hires to be mechanized welders
8 PowerWaves Networked
Smart Welder Database

- In production, weld records will be automatically created when welders are loaded using the Automatic Weld Process Selection System (AWPSS)
SmartWelder Prototyped at ARL

Smart Welder Database

• At the job site the welder will be required to enter information via barcode scanning and/or key pad entry

• This shows a sample of the data they currently check daily
SmartWelder Prototype at ARL

Smart Welder Database

- If the data provided on the job site matches the weld record created, the power supply will be enabled.
- This check will be performed in the Lincoln Weld Sequencer software.
SmartWelder Prototyped at EB

- Phase I has 8 PowerWave 455’s networked
  - Intent of this phase is to validate real time metrics for production welders
    - 4 machines are in vertical outfitting work center
    - 4 machines are in a Bay 4 part family work center
- Phase II will prove the go / no go decision can be used to validate the pre-welding checks in place to prevent wrong weld wire occurrences
  - Using production like work package data and welder work assignments produced from our “stage” environment
Green Welder Prototype

- Goal is to make new welders more productive through mechanization
- Prototype a paradigm shift in welder training
  - New hires are not provided with mechanized welding training
  - Mechanized welder training is only provided to skilled welders
- Korean shipyards consider mechanized welding a semi-skilled labor activity
Green Welder Prototype

- Run a prototype to determine the benefits of shifting how we look at new welder training
- Prototype welder training
  - Details:
    - Qualify four recently (less than 3 months) trained welders in mechanized welding
    - Perform on the job training (OJT) for the four welders with experience mechanized welders in T & I cell and NFO Mock-up
    - Fund trainers labor through IWP ManTech Task
    - After OJT Deploy the welders in the T & I cell and NFO Egg Crate and utilize the highly skilled welders currently there on harder jobs across the facility
    - Compare lbs per 8 hours metric between the new mechanized qualified welders with other recently trained welders across the facility
“Smart Welder” System

Welder Productivity Data:
- Lbs per 8 hrs
- Arc Time
- Machine Utilization

PowerWave Manager
Production Monitoring
Weld Sequencer
Smart Welder Database

EB Network

Business Objects

EB Shop Floor

- Load Welder for work assignment
- Configure Power Waves
- E-Mail Notifications
- Diagnostics and Calibration

- Automated welder start up
- Job Specific Data Input

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“Smart Welder” System

- Database to be developed in production
  - Contain all data currently used to assign work
  - Resides on the EB Network
  - Gathers information provided from welder on shop floor and job specific information from assignment process
- Provides Weld Sequencer with all information to allow for Go/No-Go decision
Process Improvements

• “Just go do it” process improvements
  • Identify issues and implement changes to process steps within the control of operations:
    – Reducing trips to tool crib
    – Stop daily set up and break down of continuing work
  • Test case start up average showed a 21 percent improvement
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Robotic Welding of Interim Products
Issue Description / Project Objective

• Issue Description
  • Need to reduce the costs of structural welding.
  • Opportunity to improve weld preparation accuracy, component assembly and fit-up, welding processes, equipment and span time for interim products.
  • Increased use of fixturing, positioning, automation and mechanization.
  • EB believes the best method to reduce welding costs is to increase the number of weld joints that are welded with automated equipment.

• Project Objective
  • Create a manufacturing cell in Bay 4 to robotically weld interim product assemblies that cannot be welded with a mechanized process.

• Previous Development Efforts
  • NJC Project S2199: EB implemented multiple track-based (linear) mechanized welding systems to concurrently weld bulkheads and implemented a T&I welding cell in Bay 4. Interim products were evaluated, but determined to require robotic welding as joint configurations are too sophisticated for mechanized welding.
Robotic Candidate Assemblies
Initial Joint Types

- Torch paths programmed
- Need to determine amount of distortion after each pass and offset tool center point for subsequent passes
- Need to transfer programs to updated virtual cell environment
Next Joint Types

- Torch paths programmed
- Need to determine amount of distortion after each pass and offset tool center point for subsequent passes
- Need to transfer programs to updated virtual cell environment
Project Schedule, Where We Are

Period of performance: 7-17-12 through 7-16-14
System Runoff At Wolf Robotics

2013, at which time members of the project team participated in a System Runoff
System Runoff At Wolf Robotics

- Project team interacting with Wolf staff during Runoff
System Runoff At Wolf Robotics

- Robot home position was reprogrammed to allow more overhead access for crane and moving parts
System Runoff At Wolf Robotics

- Robot teach pendant
System Runoff At Wolf Robotics

- Robot system controller that sits between stations 1 and 2. The operator will pull up welding programs and turn the system on from this location.
System Runoff At Wolf Robotics

- One example of the light curtain sensors.
- They were all cleverly recessed inside of the posts
Project Status / Issues

• Welded mockup at EWI on October 23rd
Project Status / Issues

- Robot cell installed at Quonset Point in Bay 4

Initial Design
Isometric View

Cell at Wolf Robotics prior to Shipping to EWI.
Project Status / Issues

- EWI developed partial penetration, full penetration and fillet OLP, bead plans, and spray parameters for limited material combination mockups in the horizontal welding position.
Project Status / Issues

- Developing qualification plate OLP, bead plans, and process parameters
  - GMAW spray - flat position
  - GMAW spray - horizontal position
  - GMAW pulsed - horizontal position
  - GMAW pulsed - vertical position

*Fixture and Plate in Vertical Welding Position*
Qualification Plate Welding

**Status**
- Bead plans modeled
  - 7ipm, 7.5ipm, and 8ipm travel speeds were modeled
  - Resulted in 27-31 passes
- Adam and Josh at EB to verify bead plans and tweak process parameters and offsets
- Per plate/position, EWI needs one week of work on robot at EB

**Week of 3/3/14 EB Visit**
- Verify welding parameters for 65kJ/in heat input
- Test “heavy weld” program created in robot studio for FLAT position
- Weld out at least 12” section of practice plate in flat position and take metallographic sections to inspect for proper bead overlap and weld penetration
How Did We Get Here?

• Conducted Fit-up Gap Study
• Developed Weld Bead Plans for Initial Joint Types and Material Combinations
• Developed Scheme for Locating Assemblies in the Cell Based on Model Placement in the Virtual Cell
• Developed Off Line Programs for Coupon Assemblies
• Welded Coupon Assemblies at EWI
• Trained EB Personnel on Basic System Operation and Robot Studio Off Line Programming
Stops and Acorn Table Model

- EWI wish list
  - Want spacers under parts to provide support and mitigate weld distortion
  - Want spacers with "plug" that fits into table hole
Subassembly Registration

Diagram showing a top view of an Acorn Table with stops marked as Y1, X1, and X2. The diagram also indicates the maximum robot reach.
OLP Development – Part Location

- FW, PP, FP joint configurations all share the same location for “Side 1”
- Reach studies and programming best practices were used to determine this location
OLP Development – Part Location

- FW, PP, FP joint configurations all share the same location for “Side 2”
- Reach studies and programming best practices were use to determine this location
From its home position, the robot first moves down close to the part.
The robot uses a “wire search” function to determine the location of the horizontal plate.

During this operation the robot slowly lowers the torch until the wire makes contact with the top surface of the plate.
The robot then uses a “gas cup search” function to determine the side location of the horizontal plate.

- The robot slowly moves the torch until the gas cup makes contact with the side of the plate.
The robot then uses a “wire search” function to determine the location of the vertical plate. During this operation the robot slowly moves the torch towards the vertical plate until the wire makes contact with the vertical surface of the plate.
The robot moves to the first robtarget along the weld joint.

When the robot searches an actual part in the shop, the weld path will be adjusted automatically if the robot detects the part is not in the programmed location.
The robot will travel in a straight line until it reaches the first robtarget along the radius.
The robot will follow the path along the radius based on the programmed robtargets.
The robot will reach the end of the radius
The robot will travel in a straight line until the end of the weld joint.
The robot will then return to it’s home position
OLP Development – Weld Path Partial Penetration

- Root pass on partial penetration joint configuration is located lower along the vertical plate
- The modeled nozzle is too large to access the root pass
- Modeled condition – 0.620 in. nozzle ID, ~0.750 in. CTWD
- As weld development progresses, nozzle and CTWD will be modified to accommodate proper dimensions
OLP Development – Weld Path Full Penetration

- Slightly better root pass access compared to partial penetration joint due to 0.25 in. root gap
- Nozzle ID is still too large to properly access root joint
- As weld development progresses, nozzle and CTWD will be modified to accommodate proper dimensions
Project Status / Issues

- **Basic System Familiarization at Wolf**
  - Completed week of January 13\textsuperscript{th}
  - 3 EB staff at Wolf for 4.5 days

- **EWI Tech Transfer to EB**
  - Completed week of February 10\textsuperscript{th}
  - Adam and Josh (EWI); Mat (Wolf) at Quonset Point for 4.5 days

- **RobotStudio Familiarization at EB**
  - Completed week of February 17\textsuperscript{th}
  - Mat (Wolf) at Quonset Point for 4 days

- **Advanced System Familiarization at Wolf**
  - Completed week of March 10\textsuperscript{th}
  - 2 EB staff at Wolf for 4.5 days
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Robotic Welding
Major Assemblies
High Level Schedule

Period of performance: 11-27-13 through 11-5-15
Task 1 – In Process

- **Task Activities**
  - Kick-off meeting - complete
  - Define criteria for applying robotic welding to Major Assemblies - complete
  - Identify candidate Major Assemblies to weld in cell – complete
  - NAVSEA approved robotic welding qualification roadmap – not started
  - Modify/sign TTP Rev A and return to CNST - complete

- **Deliverables**
  - Criterion Document (D#1) - GDEB Responsible
  - Candidate Listing (D#2) - GDEB Responsible
  - Robotic Welding System Qualification Requirements (D#3) – GDEB Responsible
  - TTP Rev A (D#4) - GDEB Responsible
Major Assembly Selection Process

- The pool of parts was derived from the Major Assemblies that are routed through High Bay and also includes assemblies manufactured in Bay 4
- These parts were evaluated to determine the best characteristics of the manufacturing cell to maximize the potential use

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<td>Generate Robotic Cell Candidate List</td>
<td>Categorized List</td>
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<td>MRP</td>
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- Generate Initial Candidate List
- Identify Additional Candidates
- Evaluate Assy Configurations
- Obtain Assy Info
- Rank Candidates
- Devel Final List
Maximum XYZ Volume of Each Category

• This is key to determining the necessary “work envelope” for the welding robot.

• The minimum size of each geometric category does not matter – the maximum size is what will define the robot’s working envelope and will dictate the proper “sizing” of the robot.

• Similarly, the maximum weight will define the size of turning or fixturing equipment needed to support all categories of Major Assemblies.
Robot Carrier Required

- Given the size of the parts – need robot carrier
  - 18- to 22-ft tall tower to raise and lower the robot
  - Fixed boom that extends roughly 3 m (9.8 ft) into the cell
Basic Cell Layout

- Basic Cell Layout with Two Stations
  - All part positioning/reorientation is manual with overhead crane (non preferred)
  - Use of fixtures designed by ManTech ARL project – not recommended
  - Option 1 – as shown above with no positioners
  - Option 2 - with prep package for Head Stock-Tail Stock (HS-TS) and Drop Center (DC) positioners
    - HS-TS and/or DC can be added in future with hookups provided – prepped for future expansion
Cell with HS-TS Positioner

- Station 1 with HS-TS (sliding TS) and Station 2 with prep package for DC in future
- Station 1 options
  - 2A = 10K kg capacity – EDR, Major Foundations (preferred option)
  - 2B = 20K kg capacity – EDR, RAFT girders, and LOT bulkheads
Cell with Drop Center Positioner

- Station 2 with DC and Station 1 with prep package for HS-TS
  - 30K kg capacity – Foundation Tanks, Collection Tanks, and Passageway (potentially box girders)
Cell Concept with Both Positioners