Advancements in Image Processing and Data Analysis for Shipbuilding Dimensional and Accuracy Control Automation (DACA)

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Problem Description

- Shipbuilders report that up to 30% of total fabrication costs can be due to rework required to compensate for poor tolerances, distortion, and lack of proper fit of components.
- New technology is needed to measure dimensional variations so that manufacturing processes can be corrected to prevent future occurrences.
Solution

• Improved analysis techniques include measuring dimensional shrinkage for cutting and welding.

• Coupled with digital photogrammetry measurements and process control information, current computer models can be incorporated to aid in predicting fabrication dimensional changes.

• This analysis will enable neat construction, where units and blocks are designed/constructed to account for shrinkage and distortion, thus eliminating the need for extra stock that is ultimately trimmed during erection.
Solution

Improve the Control of Production Processes for Each Step of Ship Fabrication

- Thermal Cutting of Plates
- Panel and Sub-Assembly Fabrication
- Unit and Block Assembly
- Erection, Hull Completion, Outfitting
Benefits

• Improved Production Operations
  – Increased dimensional accuracy and part quality
  – Improved fitting and welding operations
    • Reduced fit-up and welding time
    • Reduced welding distortion
    • Reduced rework

• Reduced Ship Construction Time and Cost
  – Reduced labor and material costs
  – Fewer schedule disruptions

• $1.8M cost savings over 5 years
Project Phases

Phase I
- Plate Cutting Proof-of-Concept Trial

Phase II
- Plate Cutting Integration
- Assembly and Fabrication Proof-of-Concept Trial

Phase III
- Assembly and Fabrication Integration
- Hull Completion Proof-of-Concept Trial

Phase IV
- Hull Completion Integration
- Fleet Services Life Cycle Support Testing
DACA APPROACH

• Phase 1
  – Initial study of plate distortion; burn machine travel; burn machine alignment; torch travel; plate distortion before, during, and after weld; targeted and targetless measurement techniques; operational parameters.

• Phase 2 +
  – Implement
    > Structural Measurement & Analysis System for Plate Burn Quality
  – Proof of Concept
    > DACA for Deck Panel Fabrication Process

• Structural Measurements & Analysis System
  – Production oriented
  – Customer driven DDX & BMD structural tolerances.
STRUCTURAL MEASUREMENTS & ANALYSIS SYSTEMS (SMAS®)

Customer Driven (DDX, BMD)
- Structure, speed, functional, deploy, survive, maintain …
- Increased construction demands (cost, quality, schedule)

- Production Oriented
  - User friendly, operator invoked automation
  - Immediate feedback of local quality
  - Long term monitoring of global quality
  - Environmentally Robust
  - Ship wide applicability
  - Architecture open and integration seamless
  - Downstream impact simulation & assessments

- Product Integration
  - MCM interface (hardware & software)
  - VMS image processing
  - PolyWorks analysis and visualization of results
STRUCTURAL MEASUREMENTS & ANALYSIS SYSTEMS (SMAS®)

- Automated System to acquire, measure, analyze, and report shipbuilding dimensional attributes:
  - Plate burn quality
  - Panel line quality
  - Assembly & Pre Outfit quality
  - Ships completion quality

- Plate Burn Quality
  - Immediate development
    - Individual plate quality
    - Operator feedback
    - A/C foundation
  - Future Correlations
    - Mechanical parameters
    - Preventive maintenance
    - Cost and schedules down stream
SMAS – PBQ

• Acquire
  – Plates burned on large tables
  – Normal table movement activates digital camera.
  – Camera automatically acquires images of burned plate at predetermined rate.
SMAS - PBQ®

• Measure
  – Acquired images are automatically transferred to SMASPBQ workstation.
  – Proprietary processing of plate perimeters and features:
    > Predetermined image overlap
    > Natural environmental lighting
    > Edge detection algorithms
  – 3D coordinates within plus/minus 0.020”
SMAS - PBQ

• Analyze
  - Automated edge detection produces a point cloud containing:
    > Plate perimeter
    > Interior cutouts
    > NC powder markings
    > Surface markings
SMAS - PBQ®

- Report CAD to As-Burn Data
  - Burn Machine Operator
    - Lengths
    - Width
    - Square
    - Straightness
    - Flatness
  - A/C Technician
    - Same as Operator
    - Simulation of downstream impact
    - ASCII text data file for SPC
SMAS - PBQ

- Simulate Impact of PBQ to Panel Fabrication
  - Dimensional Quality
  - Production Output
Direct Manufacturing Benefits - Phase II

- **25 hr reduction/panel × 110 products = 2,750 hrs/Hull**
  - Smaller root gaps due to decreased plate waviness or “banana” shaped plates = reduced welding (i.e. lower heat input)
  - Reduced welding = reduced plate distortion (waviness or “banana” shapes due to residual stresses)

- **22 hr reduction/assembly × 70 products = 1,540 hrs/Hull**
  - Better fit-ups of panel assemblies-to-decks = reduced welding + distortion
  - Better fit-ups of deck-to-deck fit-ups at deck edges = reduced welding + distortion

- **30 hr reduction/unit erection × 25 units = 750 hrs/Hull**
  - Improved unit end fit-ups = reduced welding + distortion

**Estimated Cost Savings**

5,040 hrs × $50/hr = $252,000/Hull
RESULTS

• SMAS® ~ Plate Burn Quality
  - Properly integrated off the shelf components
    > High end digital photography camera
    > Industry standard analysis software
    > Proprietary processing software
    > Flexible processing parameters and numerous algorithms
    > Customized interface
    > Three button operability now, soon to be one button
  - 3D Measurements well within plus/minus 2mm spec.
    > Single or multiple plates per nest
    > Large or small plate sizes
    > Simple or complex plate shapes
  - Costs very competitive
    > Total SMAS system < the price of some high end hardware alone.
  - Platform independent (production friendly)
    > Moving or stationary objects
    > On-line or off-line processing
    > Data easily integrated with existing software packages
LOOKING FORWARD

• DACA 3
  – Plate Quality Review
  – Deck Panel Fabrication (Panel Line) Implementation
  – Unit Assembly and Ships Completion Proof of Concept

• DACA 4
  – Panel Line Review
  – Assembly & Ships Completion Implementation
  – Fleet Service Support Proof of Concept

Panel Assembly
Panel Line Opportunities

• Monitor the plate welding process to determine plate shrinkage, squareness and distortion

• Monitor plate welding to identify distortion origin
  – At set up / tack weld
  – After welded on one side
  – After final weld

• Monitor plate stiffener attachment process to identify distortion origin
  – Check stiffener locations at tack
  – Verify stiffener locations after weld
Panel Line Opportunities

• Compare plate dimensions against data for distortion as a result of stiffener attachment.
• Assist in revising the fit and weld procedures to correct distortion encountered due to plate or stiffener welding.
• Develop a plate shrinkage database to allow BIW to quantify welding effects and predict lofting changes required to mitigate welding distortion.
Panel Line POC Results

Single Camera Approach

- (1) camera mounted on the overhead crane to take a network of images of the panel/plate concerned.
- Pattern of the image network taken can be strip like, circular, or rectilinear in nature.
- Circular and rectilinear provide significantly higher accuracy especially if a tilt swivel roll is included (enabling camera calibrations for each measurement).
- Either option will require some crane movement of to provide the proper image coverage (assuming the plate does not move during the imaging process)
Panel Line POC Results

Multi-Camera Approach

- (2) to (6) cameras arranged in an array on the overhead crane to take images of the panel/plate
- Multi-camera measurement provides 3-D data from single snap shot in time
- By properly arranging cameras (with each section of the panel/plate covered by at least (2), preferably (3) cameras) the image pattern may be as simple as a single location set-up.
- This configuration provides faster imaging rates, but is slightly less accurate due to the use of fixed (but different) calibrations for each camera
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