Ingalls Shipbuilding
A Division of Huntington Ingalls Industries

Ship Distortion Control and Production Process Improvements of Thin Plate Structures

NSRP Joint Panel Meeting
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Topics

- Overview of Ingalls Shipbuilding
- Issues with Thin Steel in Shipbuilding
- LIFT and the Robust Distortion Control Project

Ingalls Shipbuilding

- Building four classes of ships simultaneously - 12 ships under construction and one overhaul
- Sole builder of the *San Antonio*-class (LPD 17) amphibious transport docks and the *America*-class (LHA 6) amphibious assault ships
- One of two builders of DDG 51 *Arleigh Burke*-class destroyers
- Sole builder of the *Legend*-class National Security Cutters for the U.S. Coast Guard
- Largest private employer in Mississippi – approximately 11,600 Employees
- A shipbuilding division of Huntington Ingalls Industries

USCG National Security Cutter

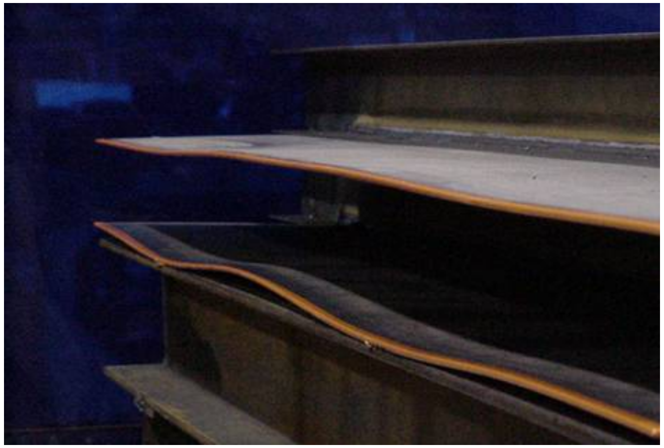
DDG 51 Surface Combatant

LPD 17 Amphibious Transport Ship

LHA 6 Amphibious Assault Ship

Thin Steel Ships Require New Thinking

- Stronger HY and HSLA steel alloys allow thinner plates to reduce weight while maintaining tensile and shear strength requirements
- Buckling strength dominates thin panel construction
- Need best practices to control distortion in all operations
  - Engineering design needs to focus on the producibility of thin steels
  - Ship production needs to focus on optimized processes
  - Workforce development needs to support the transformation



Modern Naval Ship Design Construction

- Thin steel hulls have become a trend in Naval Surface Combatant designs
  - Incorporates thinner and higher strength steel panels and structures
  - Designs increasingly becoming more light weight to increase mission capabilities
  - Meet operational objectives and improve vessel performance
  - Counteracts increase in weight due to automated equipment and weaponry
  - Naval vessels will increasingly trend toward use of thinner, light weight/high strength steel designs

- Thin steel designs cause significant fabrication difficulties
  - Residual weld stress induced-distortion due to high heat input on thin steel
  - Panel shrinkage and dimensional control issues
  - Workforce training with techniques needed to mitigate thin steel construction difficulties
  - Need to overcome the challenges of implementing newer unfamiliar technologies to aid in reducing production costs and schedule issues with thin steel fabrication

LIFT

- What is it?
  - A Detroit-based public-private partnership designed to help develop and deploy advanced lightweight metal manufacturing technologies, and implement education and training programs to better prepare the workforce today and in the future
  - A founding member of Manufacturing USA, a group of public-private partnerships with distinct technology focuses working toward a common goal: to secure the future of manufacturing in the United States through innovation, education, and collaboration

- What are its focus areas?
  - Manufacturing Technology Transition
  - Education and Workforce Development

See www.lift.technology for more information

LIFT Robust Distortion Control Project

- This project brought together world class engineering and manufacturing experts in distortion modeling, distortion mitigation, cost modeling and production innovation
- The technical goals were:
  - To identify areas of lightweight steel manufacturing that present the greatest challenges to the shipboard application of lightweight structures
  - To develop novel, multi-scale, integrated computational materials engineering (ICME) based prediction tools for modeling applications in lightweight material manufacturing
  - To validate ICME tools can be used to quantify distortions associated with the build process to improve:
    - Storage, lifting and handling of structures
    - Fitting and welding processes
    - Design of unit structures and erection joints
    - Weld and build sequencing

Project Team Members and Roles

- Ingalls Shipbuilding: Project lead
- The Ohio State University: ICME material modeling, residual stress
- University of Michigan: Distortion measurement and modeling
- Mass. Institute of Technology: Cost and process flow modeling
- Edison Welding Institute: Residual stress, shop floor implementation
- ESI – North America: ICME, distortion model software developer
- NSWC – Carderock Division: ICME material modeling, structural testing
- American Bureau of Shipping: Classification and design consulting
- Comau: Innovative fixturing support

Project Technical Subgroups

In order to manage the work on the project, five technical subgroups were formed based on the tasking related to the project goals:

- Dimensional Control & Measurement team
  - UM and Ingalls
- Cost Modeling & Process Development team
  - MIT and Ingalls
- ICME Modeling, Testing and Validation team
  - ESI, EWI, OSU, NSWCCD, UM, ABS and Ingalls
- Residual Stress Measurement team
  - EWI, NSWCCD, OSU, UM, ABS and Ingalls
- Lightweight Structures Manufacturing Training & Implementation team
  - UM, ESI, MIT, EWI and Ingalls

Cost Modeling Development

- Specific quality related costs are difficult to capture; prior to this project the main quantitative cost linked to distortion was flame straightening
  - Additional costs associated with distortion (fitting, trimming, increased welding time, remediation activities to account for unfairness) were not disaggregated from cost data
- Cost modeling approach
  - Disaggregate cost/rate data to a detailed activity level at each workstation
  - Downstream cost predictions were made based on the addition or elimination of activities resulting from upstream quality/distortion changes
  - UM aided by executing a Bayesian Network analysis from historical data to help predict distortion levels and occurrences
- The project is expected to achieve unprecedented levels of distortion mitigation, controlling dimensional accuracy and improving cost confidence in order to increase quality and efficiency of hull production

Workforce Training and Implementation

The following training-related efforts were pursued:

- Engineer Training for ICME
  - Lead: ESI (Lead), UM, Ingalls (Co-Lead)
  - Train Hull Tech and Production Engineers on use of the ICME software to improve design for producibility (DFP) and predict optimum production procedures based on the computer modeling output
- Production Craft Training
  - Lead: EWI (Lead) , UM, Ingalls (Co-Lead)
  - Train production craft personnel on best practices for various hull structural conditions. Leverage past Thin Steel Welding Curriculum and build on this training tool to add other procedures developed through the Design of Experiments and ICME tasking
- Industrial Engineering and Cost/Pricing Personnel Training
  - Lead: MIT (Lead), Ingalls (Co-Lead)
  - Train industrial engineers and cost/pricing personnel on how to utilize the cost model developed throughout the project and weigh various production procedure options from the ICME modeling tool to determine the most economical and cost efficient solutions

Progress to Date and Future Efforts

Completed Activities:

- Baseline NSC 8 unit 4130 was built and all data necessary for modeling was collected and analyzed
- The DOE for the test articles was completed and distortion scans were completed for analysis of design variables
- Material models were developed for ABS Grade DH36, HSLA 65 and HSLA 80 steel alloys to support ICME
- Cost models were developed to predict costs in the various workstations associated with unit fabrication
- A full-scale mock-up test unit was built using the recommended process changes for distortion data and production cost was compared with NSC 8 baseline unit 4130

Future Activity:

- Develop material models for HSLA 100, HY 80 and HY 100 steel alloys

Final Mock-Up Completed

- Better dimensional accuracy
- Significant labor cost reduction

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