Development of a Fast Analysis Solver for Welding Sequence Optimization of Ship Structures

All Panel Meeting Presentation

March 2023

INGALLS SHIPBUILDING
A Division of HII

HII Ingalls Shipbuilding

- **Largest manufacturing employer** in Mississippi
- **Major contributor** to the economic growth of Alabama and Mississippi
- **Largest supplier** of U.S. Navy surface combatants
- Only shipyard **simultaneously building 4 classes** of ships
- **Comprehensive life-cycle services** for CG 47, LPD 17 and LCS class ships

***America*-class**
Large Deck Amphibious Assault Ships

***San Antonio*-class**
Amphibious Transport Dock Ships

***Arleigh Burke*-class**
Aegis Guided Missile Destroyers

***Legend*-class**
National Security Cutters

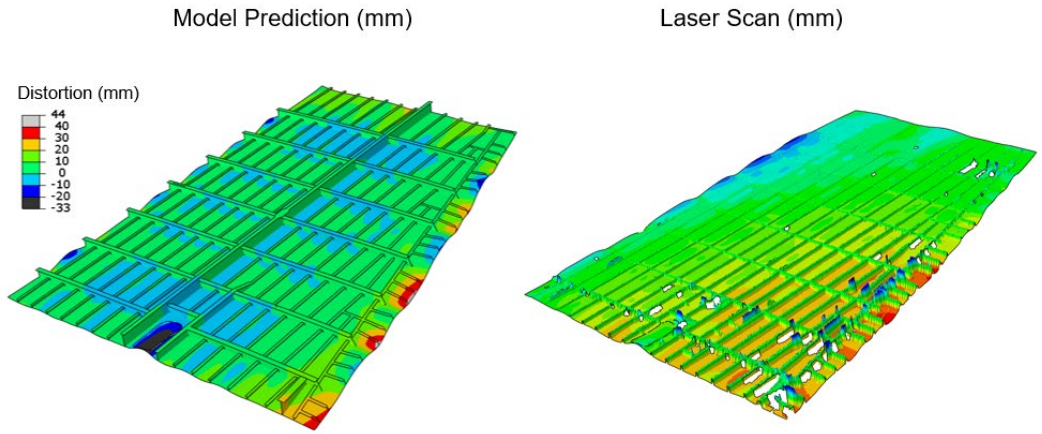
11,000
employees

800
acre shipyard

85 Years
History of building world-class ships

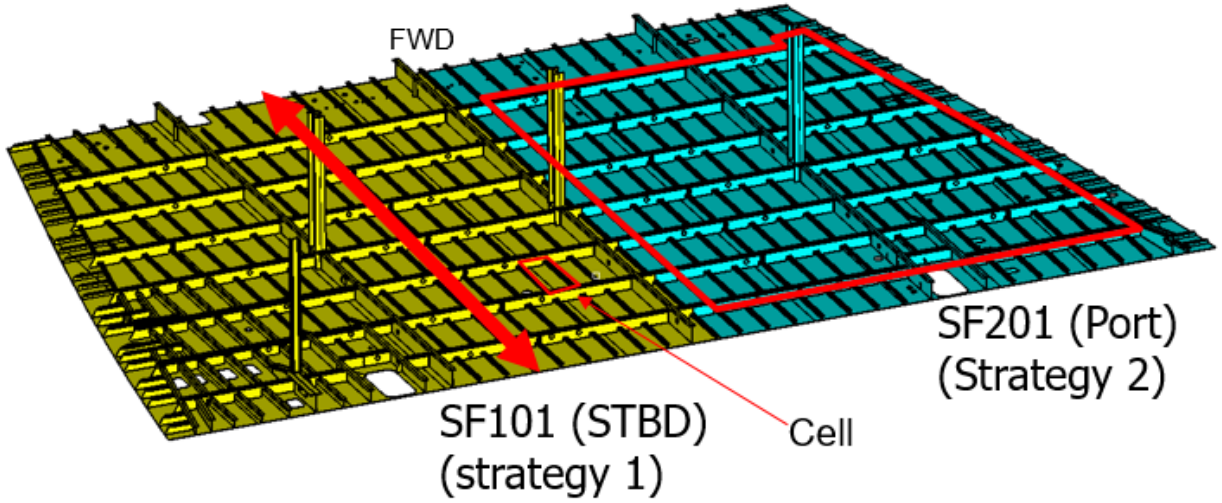
Problem Statement

- Materials are exposed to significant thermal and mechanical stresses during welding that affect dimensional accuracy, production schedules, labor hours (fitting, welding, rework, etc.), and structural performance
  - Many variables influence the stresses and resulting impacts
- Structural analyses that simulate the thermal and mechanical stresses are time consuming
  - Simulations to optimize welding sequences and minimize impacts are cost prohibitive
  - Production uses other metrics for weld sequencing



Example: Stiffened Panels

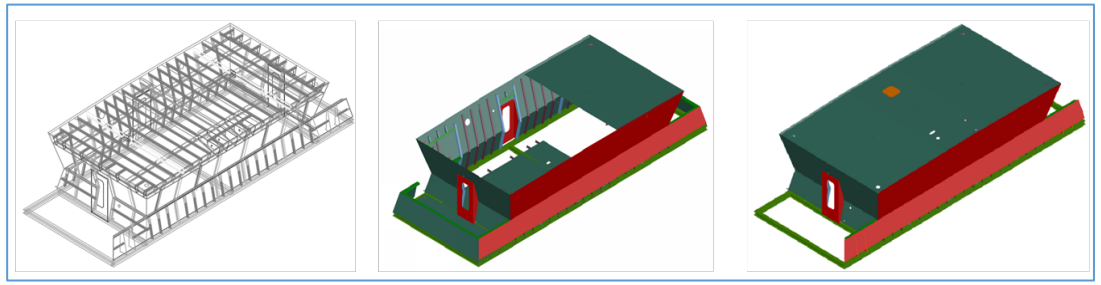
- Robotic welding increasingly used in panel construction
- Weld sequencing is currently optimized for travel time, not distortion reduction
- Due to the complexity of non-linear thermal elastic-plastic analyses, a fast finite element analysis (FEA) solver is needed to efficiently optimize weld sequences for distortion reduction

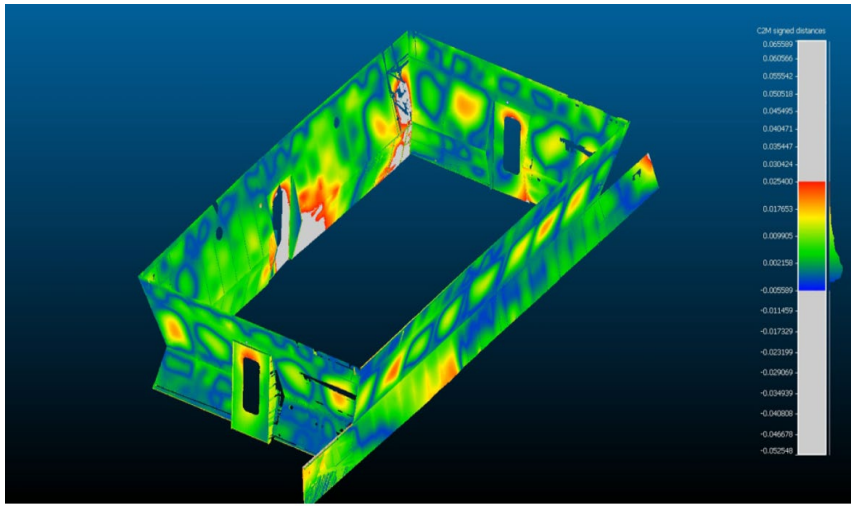


- Current analyses tools are limited to running local models and mapping to the global model due to computational time
  - Limits the amount of analyses
  - Reduced model accuracy

Example: Unit Assemblies

- Units are much more complex than stiffened panels
- Due to computational time, current FEA tools are not practical for unit assembly analysis





Project Goals and Desired Outcome

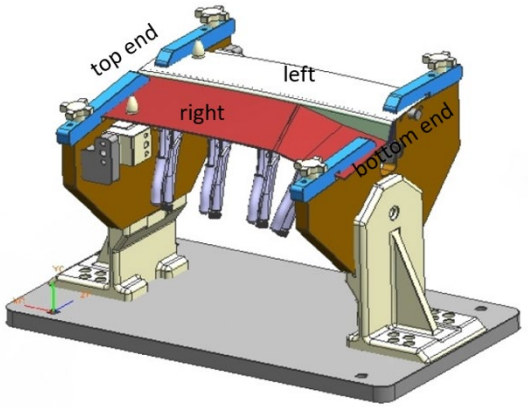
- Goals
  - Adapt the DR-Weld transient elastic-plastic finite element analysis (FEA) solver developed by Oak Ridge National Laboratory (ORNL) for the automotive and nuclear industries to support shipbuilding applications
  - Apply the FEA solver to simulate fabrication of production panels, unit assemblies, and alignment critical foundations to examine its feasibility, effectiveness, and accuracy
- Desired outcome: a transient elastic-plastic FEA solver for welding simulation that will be feasible in a shipbuilding environment

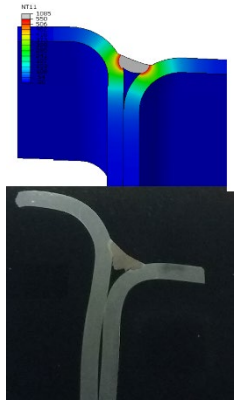
DR-Weld: Digital Reality Welding Simulation

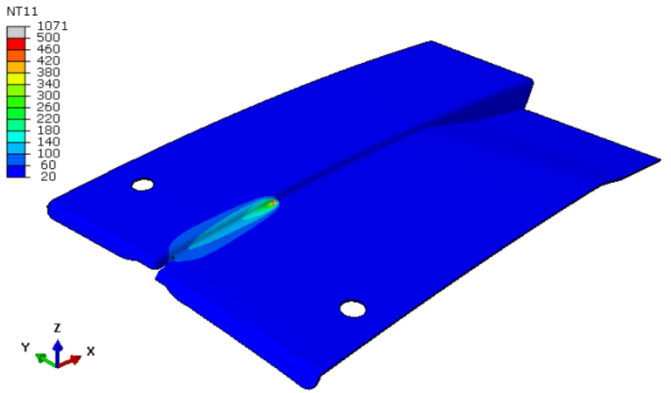
- High-performance computational code that drastically speeds up high fidelity welding and additive manufacturing (AM) simulation
  - Developed and patented by ORNL
  - Designed to take advantage of modern HPC computers
  - Rigorous physics representations of welding process (transient thermal-mechanical problem) without unnecessary over-simplification
- Recognized by the technical community for its innovation in welding and AM simulation
  - 2021 Heinz Sossenheimer Software Innovation Award, International Institute of Welding
  - 2021 ORNL Research Accomplishment Award
  - 2022 A. F. Davis Silver Medal Award, American Welding Society

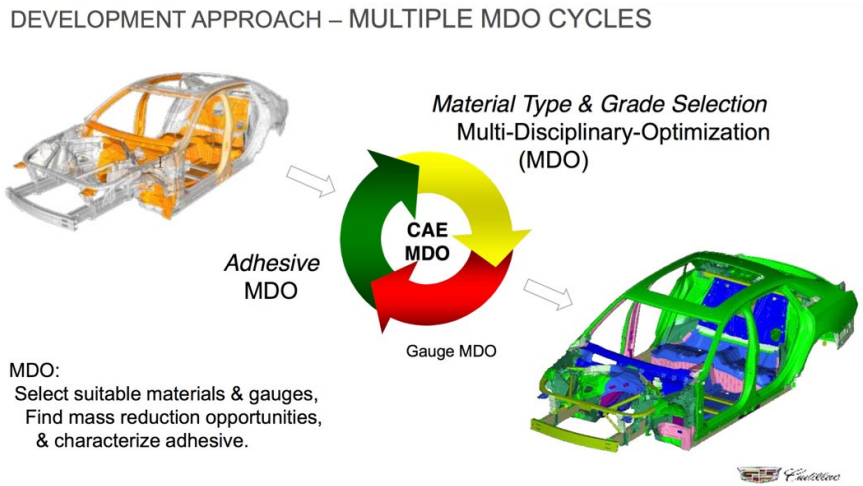
Impact of Digital Reality Welding Simulation

- Achieving >100 times computational speed increase can revolutionize how welding simulation tools are used in design, engineering, and fabrication optimization of welded structures
  - High fidelity simulation that required weeks could be done within 24 hours
  - Welding innovations can be evaluated numerically rather than relying on iterative physical trial and error
  - Integrated computational welding engineering of welding fabrication options or scenarios in a practical time frame is enabled









Project Team

- HII Ingalls Shipbuilding
  - Steve Scholler, Yu-Ping Yang, John Walks
- Austal USA
  - Shawn Wilber
- Oak Ridge National Laboratory
  - Zhili Feng, Jian Chen
- Hexagon
  - Fernando Okigami, Michael Taylor
- General Motors
  - Hassan Ghassemi-Armaki
- ATI (NSRP Program Administrator)
  - Ryan Schneider, Project Manager
- HII Newport News Shipbuilding
  - Alicia Harmon, Program Technical Representative

Proposal and Project Timetable

- Initial proposal submitted in July 2022
- Selected for funding in September 2022
- Final pricing and statement of work submitted in November 2022
- Task Order awarded March 2023
- Two project phases of 12 months each
  - Focus of Phase 1 – stiffened panel analyses
  - Go/no-go decision at end of Phase 1
  - Focus of Phase 2 – unit assembly analyses

Summary

- Status: Task Order recently awarded
  - Subcontracts are in work
  - The project team is eager to begin!

Questions?