

Low-Cost Friction Stir Welding of Aluminum for Littoral Combat Ship Applications

Objective: Develop prototype low-cost, transportable FSW machine for stiffened panel production at LCS shipyards

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Navy Metalworking Center A ManTech Center of Excellence

Project Background

- The Littoral Combat Ship (LCS) program currently has two teams, headed by lead system integrators Lockheed-Martin and General Dynamics

Lockheed-Martin Team



**Launch of LCS-1 "Freedom" at
Marinette Marine Corporation,
23 September 2006**

VS.

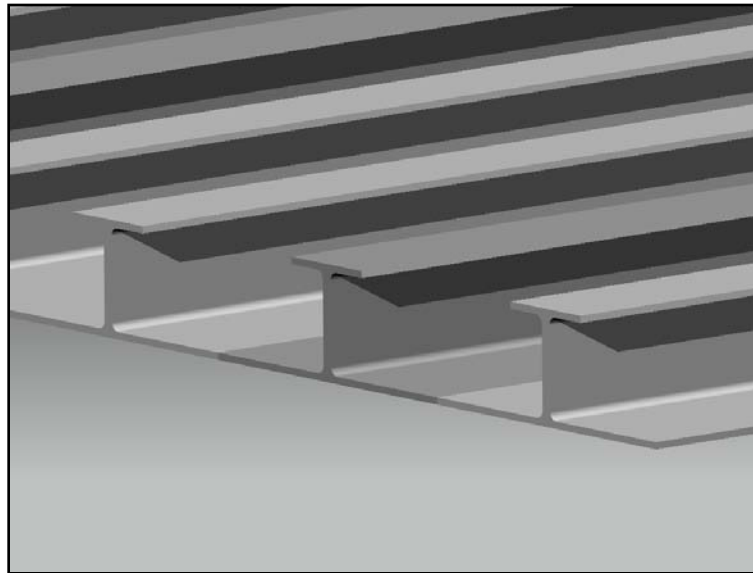
General Dynamics Team



**Independence-class LCS ship
concept drawing, keel laid at Austal
USA, 19 January 2006**

Program Background

- The Lockheed Martin Team LCS design makes extensive use of stiffened aluminum panels for construction of the ship's superstructure
- These panels are built up from extruded aluminum shapes using friction stir welding (FSW) as the joining method

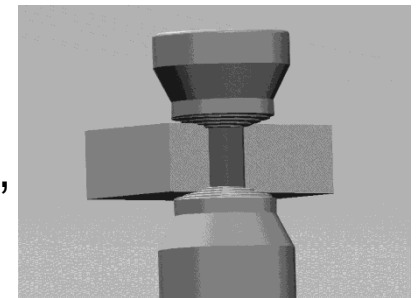


Program Background

- **Problem Statement**

- Current FSW machines for production cost >\$1M
 - Multiple powered axes
 - High process forces
 - General-purpose equipment is overkill for many shipyard uses
- High capital and recurring costs require multi-shift, continuous machine operation and an extensive backlog of work to justify the expense
- Off-site production by FSW suppliers limits panel by transportation method

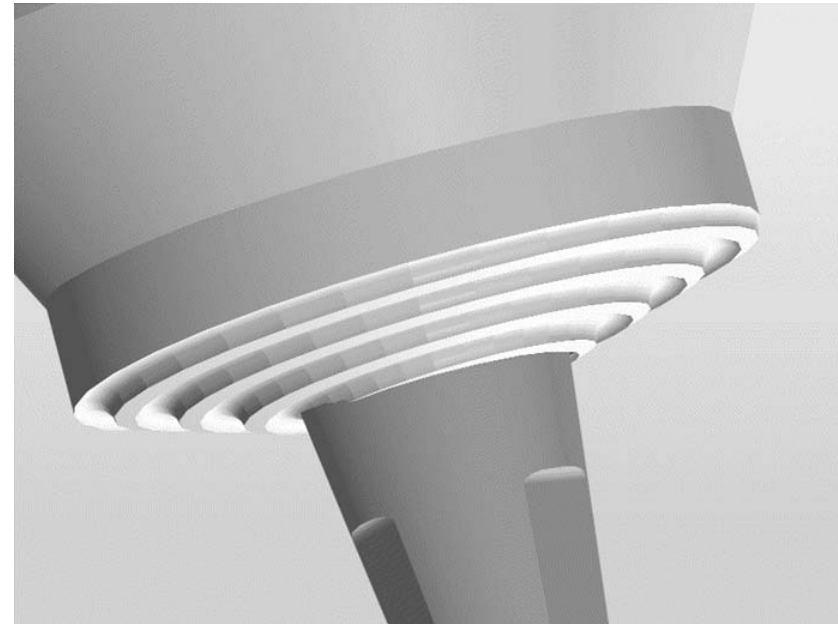
- **Breakthrough Technology**
 - **New welding tool technology makes possible a very low-cost, transportable welding machine**
 - Fixed geometry bobbin tool
 - New conventional FSW tool designs
 - New equipment design approaches
 - **Now possible to produce a very low-cost machine for welding extrusions**
 - Single-purpose machine—single axis of motion
 - No load transfer to floor—no foundations to install
 - Minimal instrumentation
 - Transportable—within yard or between yards
 - Produces very large panels—no longer “truck limited”
 - Provides most of the stir welding shipyards need



Bobbin FSW Tool

Fixed-Geometry Bobbin Tools

- Combination of the scrolled shoulder with the tapered profile allows embedding of the shoulder in the workpiece
- Scrolled shoulder + tapered profile = improvements in tool performance:
 - variable shoulder depth
 - fixed-geometry bobbin
 - mismatch
 - complex contour



**Tapered shoulder design, patented by CTC
(US patent 6,669,075)**

Fixed-Geometry Bobbin Tools

- “Self-reacting” tools require actuation of the pin relative to the shoulder, adding a machine axis.
- The tapered shoulder design makes practical a fixed-geometry bobbin tool:
 - usable on all welding machines, machine tools
 - simple operation - adjust gap to accommodate plate variation and do load controlled weld with zero plunge force



Fixed-geometry bobbin tool

**Weld between
4mm and 4.75mm
5xxx Al**



Customer Benefits

- **Locating FSW at Shipyard:**
 - Enables production of full-size panel, not sized for road transport
 - Eliminates or reduces transportation costs
 - Eliminates or reduces arc welding for panel assembly
 - Increases panel quality by minimizing distortion
- **Low-Cost FSW Machine:**
 - Enables positive business case for FSW adoption for many applications requiring stiffened aluminum panels
 - Will produce welds certified by ABS and NAVSEA and is a freely available production machine design

Program Approach

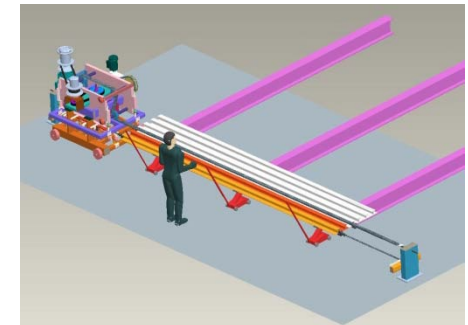
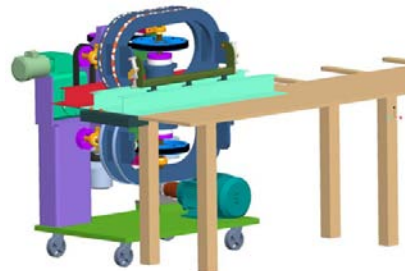
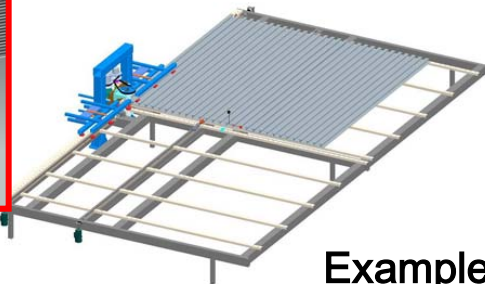
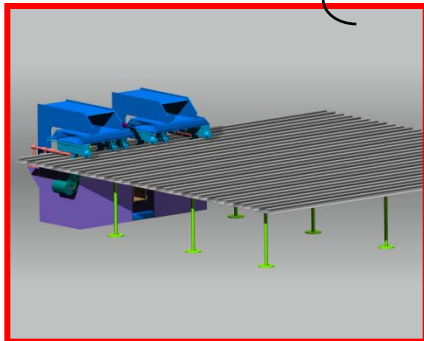
Navy ManTech project to develop & demonstrate LC-FSW

Phase I
9/06 – 8/07

- Design and develop drawing package for low-cost FSW system
- Work with extrusion suppliers to reduce geometric variability in extrusions
- Characterize FSW joints produced in representative materials

Phase II
9/07 – 10/08

- Build and integrate welding system
- Test and demonstrate the welding system at NMC, then transition to the target shipyard
- Demonstrate fabrication of production panels at the shipyard
- Make the machine design and test data available to DoD contractors free of charge so duplicate systems can be implemented in shipbuilding or other industries



Example Machine Concepts

Project Team Members

- **PEO Ships, PMS 501 LCS Program Office – Stakeholder**
- **Lockheed Martin MS2 – LCS System Integrator**
- **Naval Sea Systems Command (NAVSEA) 05P24 – Navy Technical Warrant Holder**
- **Naval Surface Warfare Center, Carderock Division Code 611 – Navy Technical Authority**
- **American Bureau of Shipping (ABS) – Technical Warrant Holder**
- **Marinette Marine Corp. – LCS Builder**
- **Bollinger Shipyards, Inc. – LCS Builder**
- **Advanced Joining Technologies – FSW Service Provider**
- **Friction Stir Link – FSW Service Provider**
- **Navy Metalworking Center (NMC) – System and Process Development, Project Management**

- **Low-cost FSW equipment presents opportunities:**
 - Expanded use of FSW on LCS ships and other Navy platforms
 - Demonstration of a new type of FSW equipment
 - Reduce cost of Navy ships
 - Expand FSW to other DoD products requiring lightweight, stiffened panels
 - Pathfinder for other low-cost FSW concepts, such as FSW for thick section aluminum plate and friction stir processing