Friction Stir Welding for Naval Applications

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Mechanical
Engineering

FRICTION STIR WELDS OF HSLA STEEL PANELS FOR SHIPYARD APPLICATIONS

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- Johnny DeLoach, Program Manager, NSWCC
- Maria Possada, NSWCC
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- MTI, South Bend, IN

Objectives of Full Scale FSW Demo

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- Successfully demonstrate FSW of large steel panels in a naval ship yard
- Design, manufacture, install a FSW machine capable of FSW 0.25" thick x 8' wide x 55' long HSLA steel panels
- One year time frame

Why FSW steels

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- Less Distortion
- Lower energy costs (Reported by Mazda)
- Less waste (slag)
- No hazardous fumes (Rockwell Scientific 2004)
  - ➔ Airborne Emissions in 304L

Element	TIG	FSW
Cr	0.25	<0.03
Cu	0.11	<0.03
Mn	1.88	<0.02
Hexavalent Cr*	0.02	<0.01

All values in mg/m^3

*Hexavalent Cr is typically low with TIG versus other fusion welding practices

Conceptual Design

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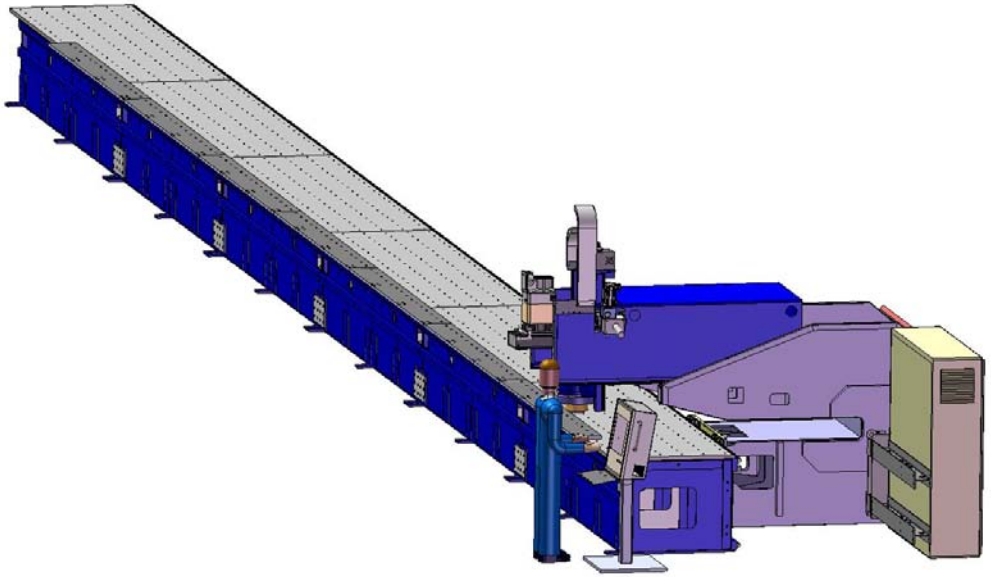
- Modify an existing production machine at MTI (South Bend, IN)
- Modifications:
  - Make additional table sections
  - Design and manufacture a "stiff" 8' C-frame
- *Next issues to address*:
  - How to align and fixture two 8' wide X 55' long *pieces of paper*?



Restraining Panels to Anvil

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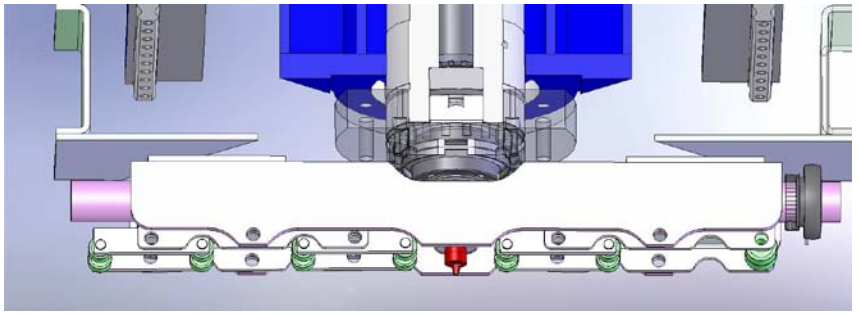
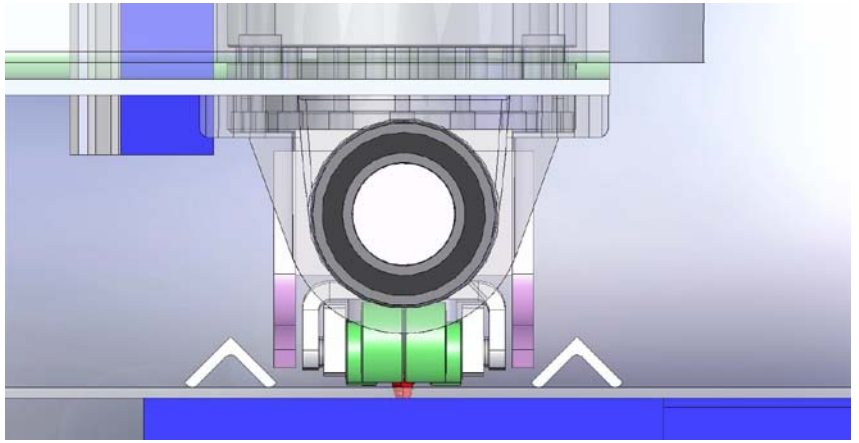
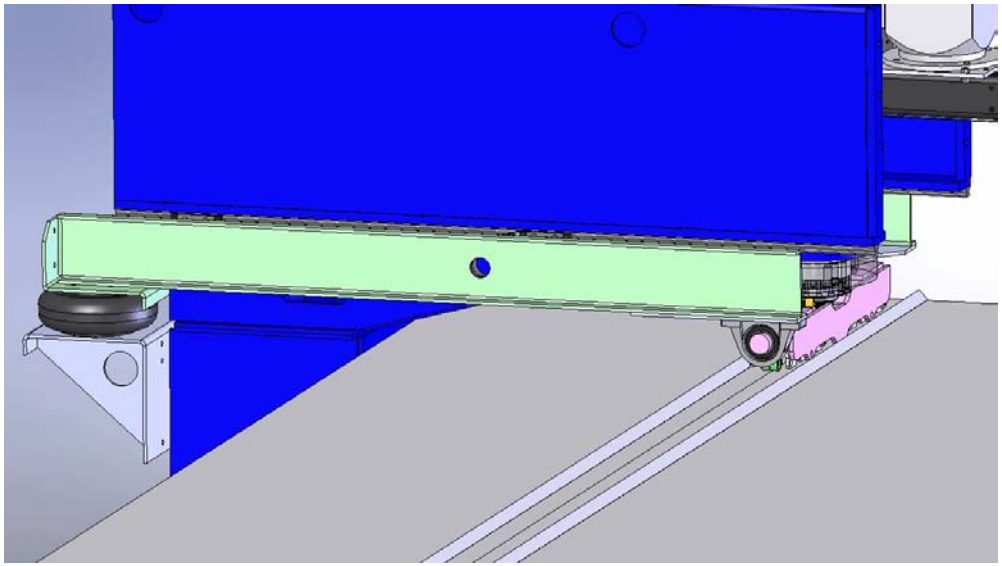
- Holding panels in contact with anvil is critical
- MTI designed a gimbal system into the C-frame







Initial Proof of Concept

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Full Scale Demo Challenges

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- Performed at Northrop-Grumman Gulf Coast Shipyard in Pascagoula, MS (Lee Kvidahl)
- Surface condition of panels
  - Continuous layer of rust
  - Thickness of mill scale varied along length of panels
  - ➔ Caused process to be very unstable
  - ➔ Once mill scale and surface oxidation removed: process very stable
- Joint Gap
  - ➔ Originally up to 10 mm

FSW Large Steel Panels

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Distortion in FSW Large Steel Panels

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Distortion in FSW Large Steel

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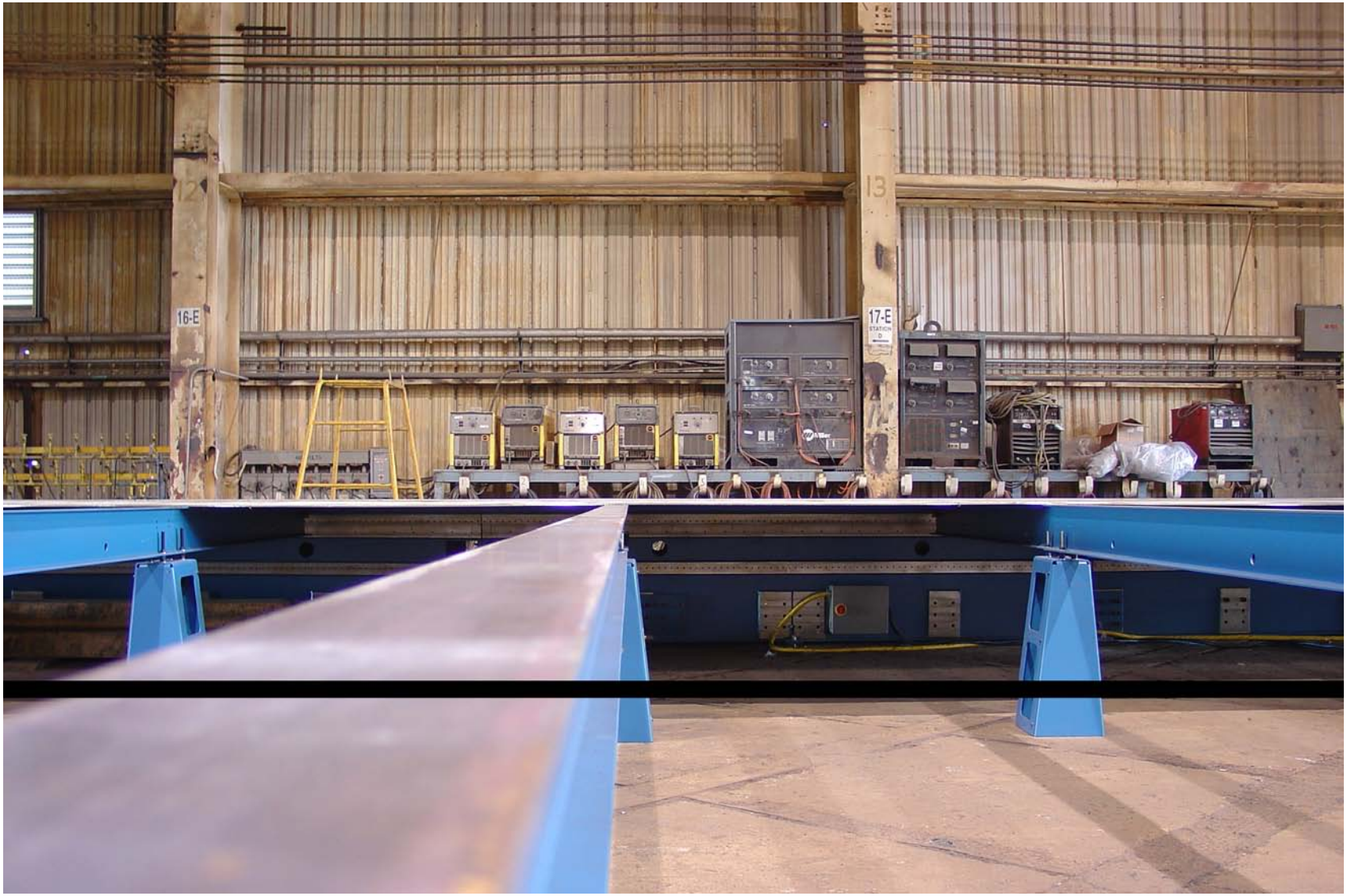

Distortion in FSW Large Steel

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NG employee south of the panel shop was “extremely” excited about lack of distortion!!

Lessons Learned

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- Cannot run stable weld through heavy oxide and/or mill scale
  - ➔ Must be ground on top surface and along panel edges
- Maximum weld gap: 1.5 mm
  - ➔ Plates edges must be prepared to meet maximum gap
- Heavy lateral clamping not required
  - ➔ Used lateral clamps to align plates
  - ➔ Only hand snug during welding
- Gimble system kept plates in contact with anvil
  - ➔ Reduced need for extensive clamping in close proximity to weld
- Real-time process control is essential
  - ➔ Implementing new control algorithm as a result of one week of testing

Summary

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- Successful Full Scale FSW Demonstration in a Production Environment
  - Demonstrated:
  - Large scale production capabilities: 18m (55') welds
  - "Reduced" distortion
    - There was NO MEASURABLE distortion
  - Travel speeds up to 350 mm/min (14 ipm)
  - Tool life >50 m (150')
  - Acceptable weld gap up to 1.5 mm
  - Acceptable limits on scale and oxide
  - Fixturing requirements may be less than anticipated

Portable Friction Stir Welding Technology for Aluminum Fabrication

Contributors:
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NSRP
August 17, 2010

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- NSWCCD — Johnnie DeLoach and Maria Posada

Program Elements

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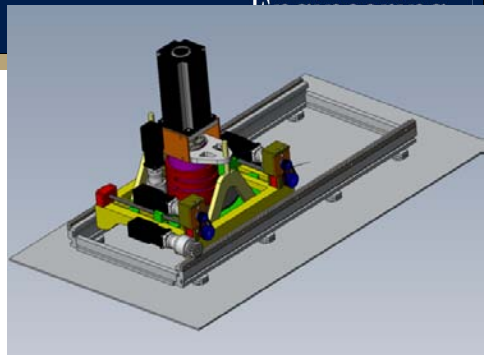
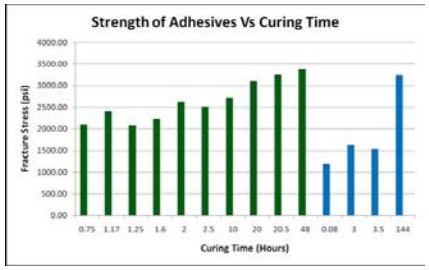
Objective:

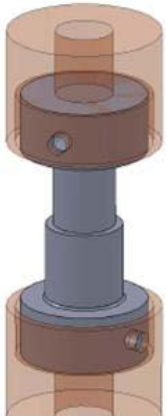
Design, build and demonstrate a portable FSW system capable of field repair in aluminum alloys



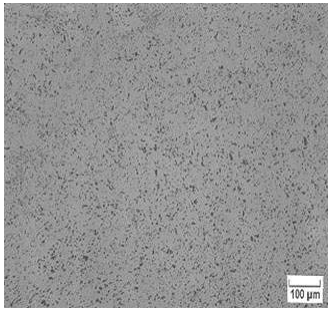
Detailed engineering designs



Adhesive strength



Adhesive testing



Weld parameters & metallography

Tool designs for min. loads

Key Program Elements

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- Portability and versatility for 6 mm thick AA 5083 repair
- Low loads via tool design and weld procedures
- Easy attachment and removal of FSW machine
- Ability to weld repair in flat, eventually vertical and overhead orientations and eventually ferrous alloys
- Low weight system design, i.e., 2-person operation
- Modular to adapt to short and long lengths
- Key system elements
  - Spindle assembly
  - Spindle carriage
  - Guide tracks
  - Z-position control
  - Seam following capability (non-linear)
  - Adhesive attachment approach

Conceptual Design of Portable FSW System

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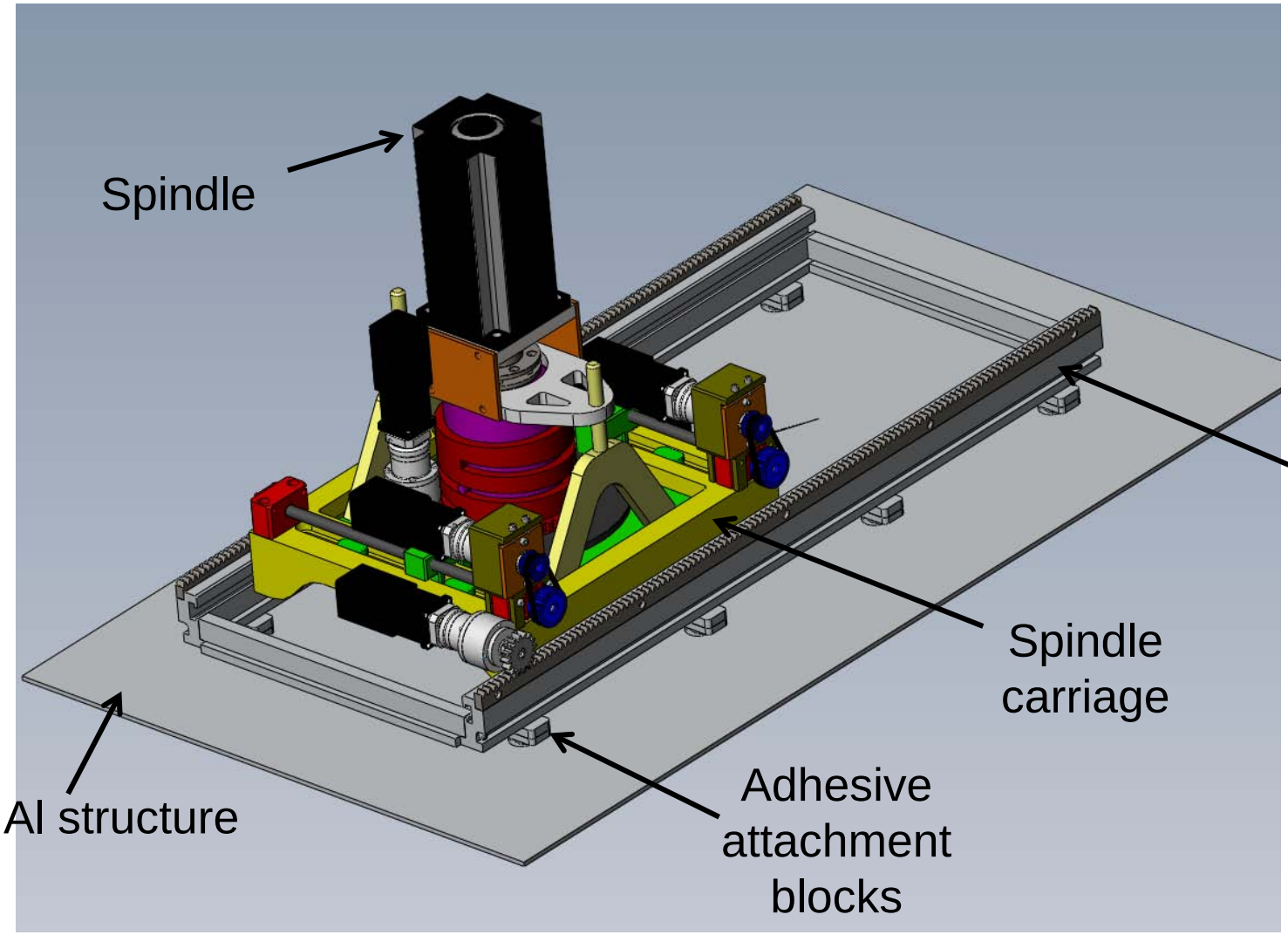

Tool designs and weld parameters for optimum repair conditions

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- Two-piece tools (pin and shoulder): allows the scroll to end at the pin and easy compares shoulder/pin combinations
- Focused on 0º tilt scroll shoulders for FSW system simplicity
- Low travel speed and high rpm parameters for lower loads
- Higher speed and lower rpm for lower temperature
- Loads and torque = f(ipm, rpm, tool depth, and tool design)

Establish Minimum Process Loads

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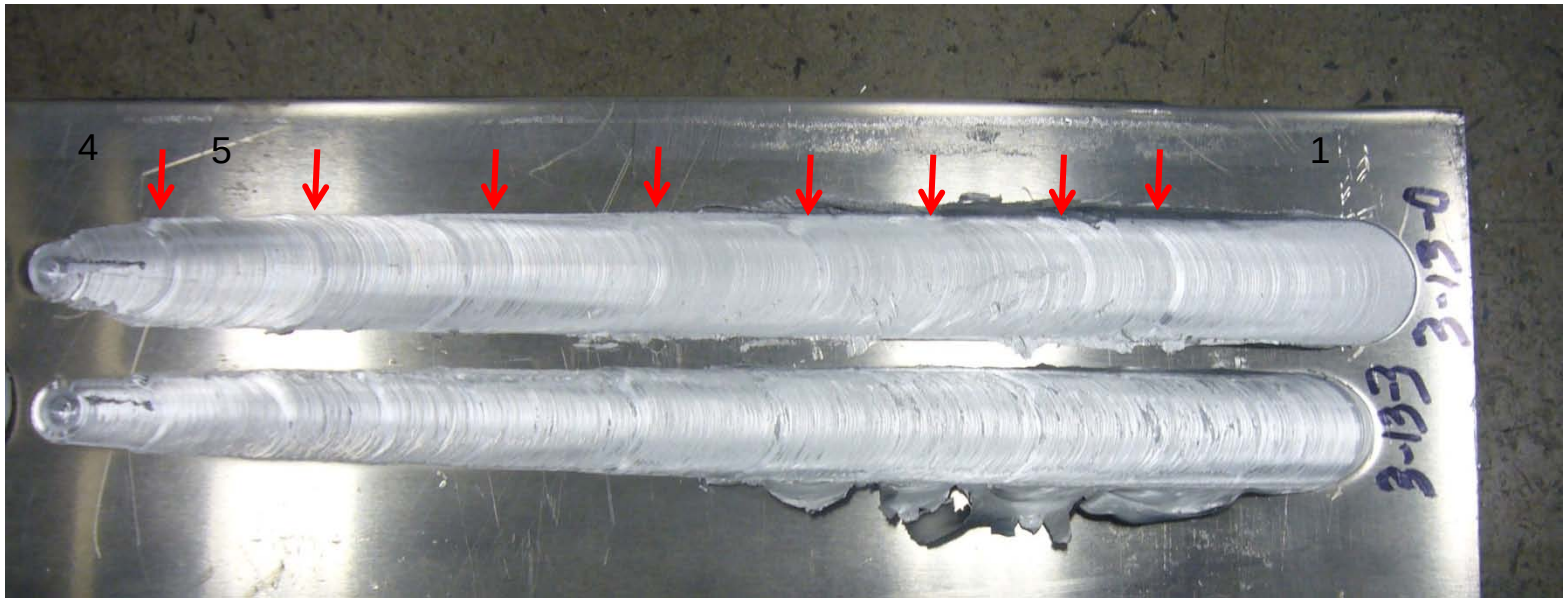

1) The initial plunge is deeper than necessary
2) After a short weld, the tool is extracted in 0.005 inch increments (↓)
3) All loads on the tool are recorded
4) Once a surface defect occurs, the weld is stopped
5) Metallography is performed to identify where the lowest normal load + defect free weld occurs for each tool combination

Load response as a f(rpm & depth)

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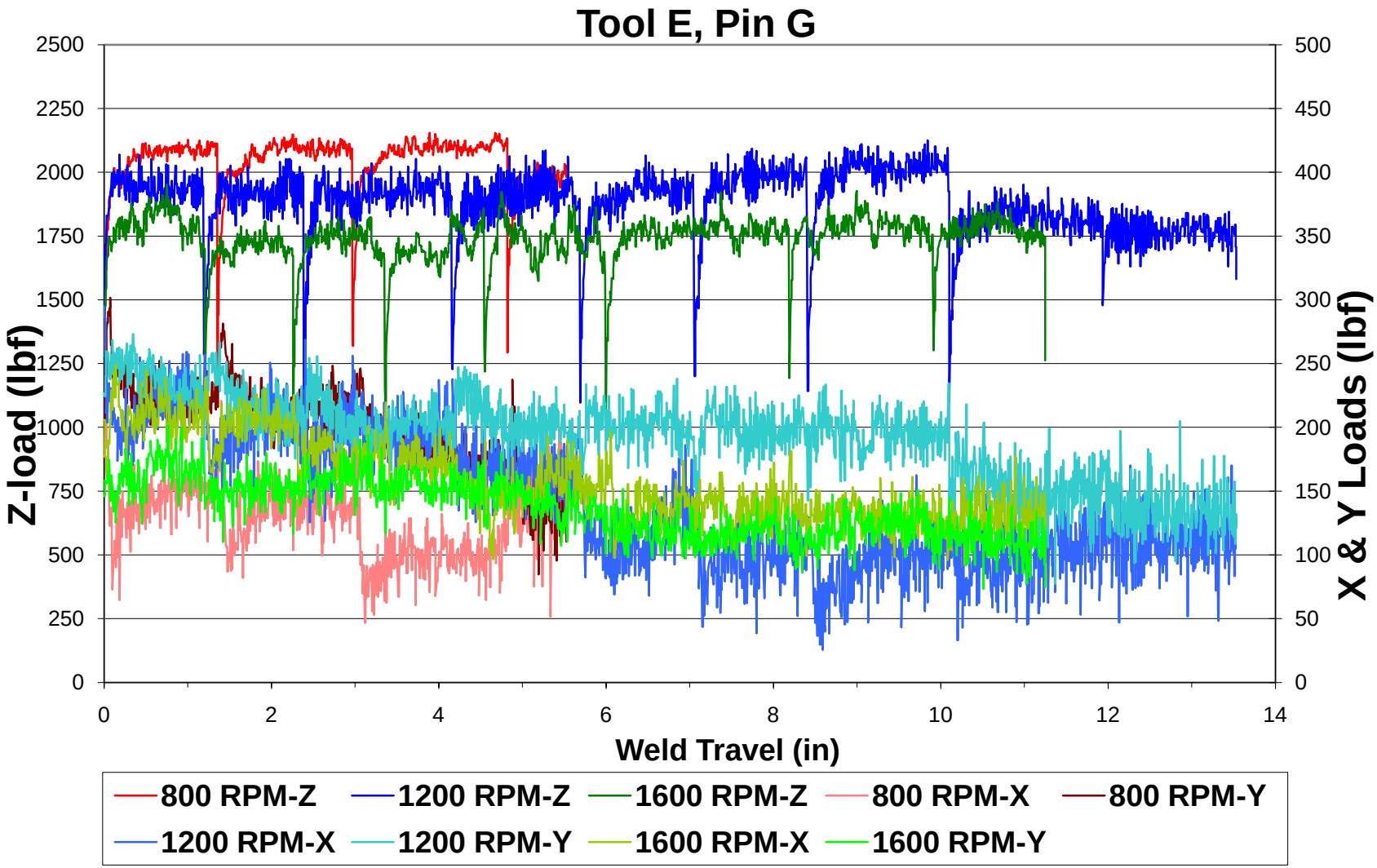

X is in the direction of weld travel and Y is transverse to the weld direction

Summary of response = f(ipm)

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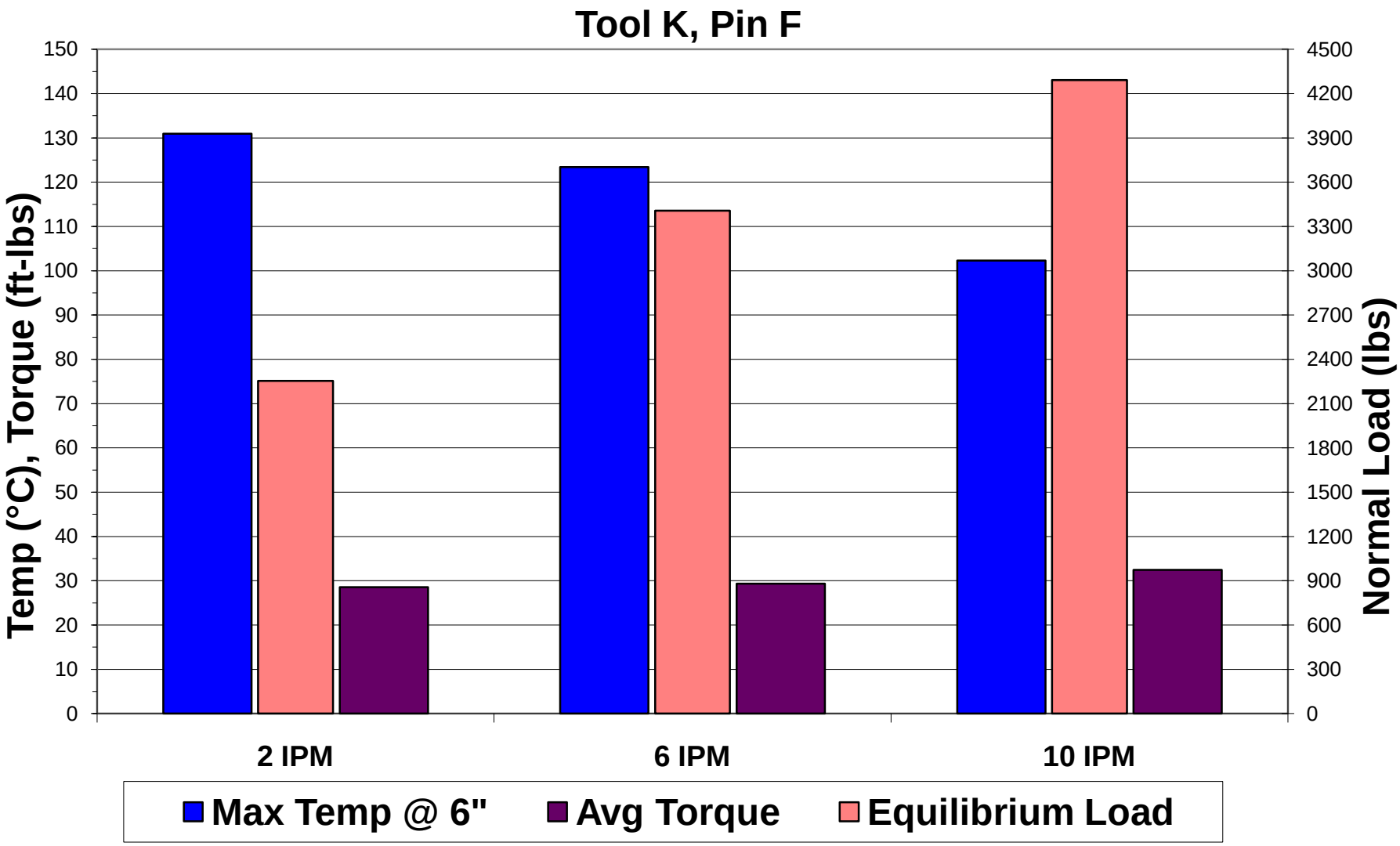

Track Attachment Approach: Adhesives

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Criteria:

- No solvent
- Rapid bonding time
- Non-toxic
- Easy application
- High tensile and peel strength
- Impact strength
- Moderate or room temperature
- Easily removable
- Low cost
- Portable
- No change to structure properties or surface condition
- Low applied load (if any)

Track Attachment Approach: Adhesives

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Adhesives evaluated and summary observations:

✓Thermoplastics: Moderate strength but requires elevated temperature application and applied load

✓Cyanoacrylates: Meets all criteria but intolerant of gaps

✓Acrylic: Meets all criteria & is very high strength

✓Instant adhesives: Low strength

✓Bonding tapes: Low strength and considerable elasticity

Tensile Strength Aadhesives

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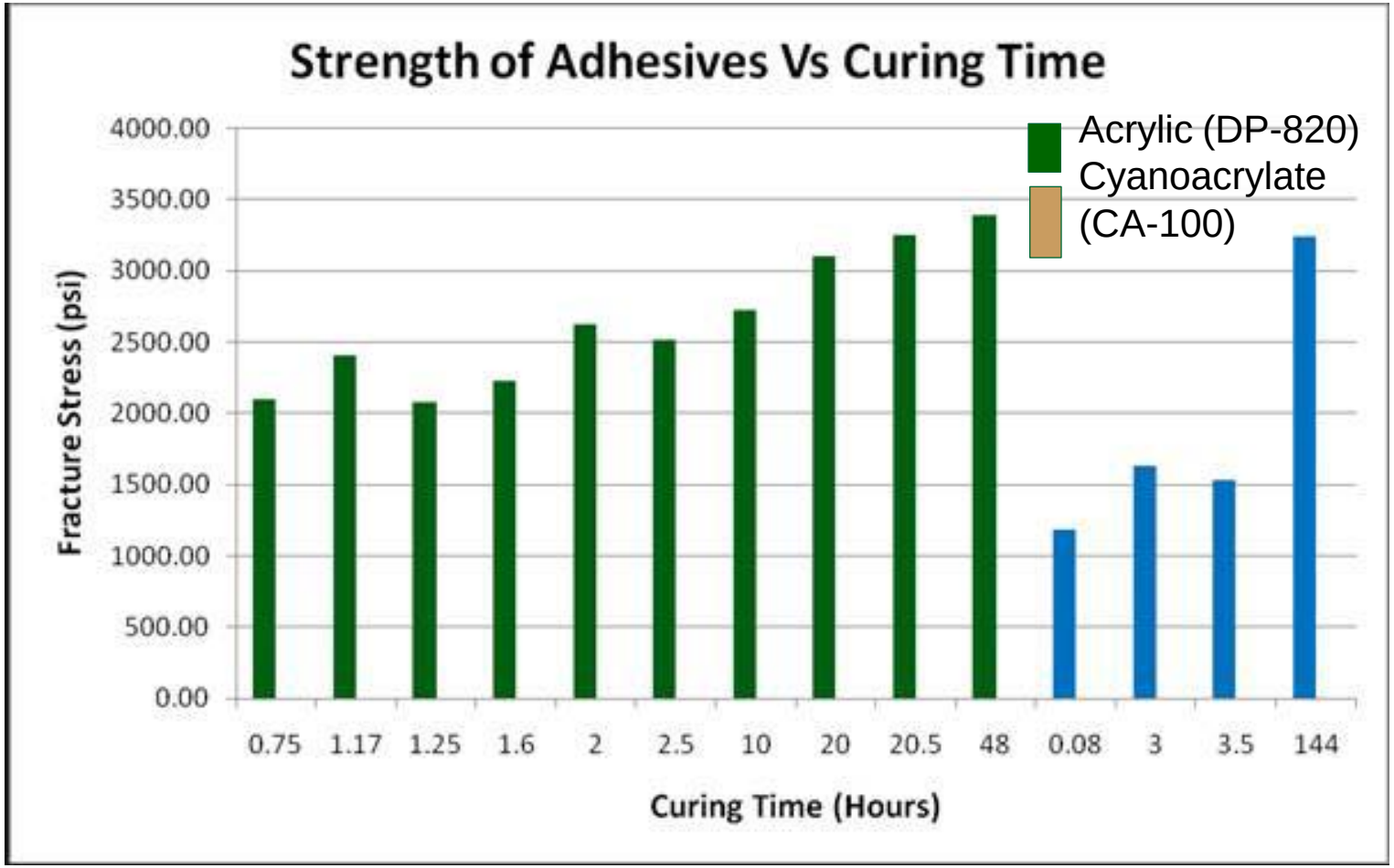

FSW Tool Loads, Normal to the Structure, will be <2000 psi (13.8 MPa)

Surface temperatures during FSW

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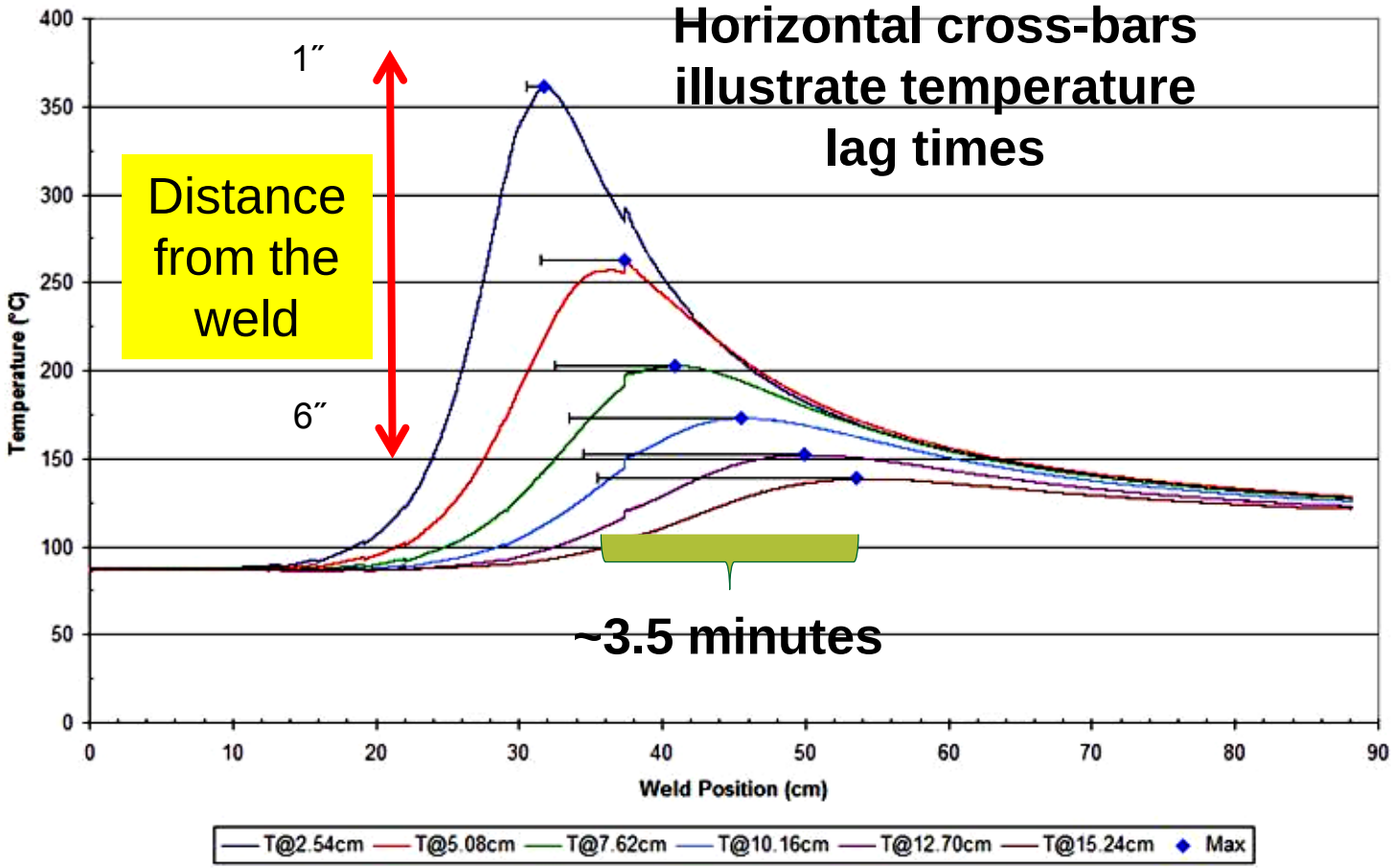

Adhesives will need to resist load at moderately elevated temperatures

12 mm thick AA 5083, 6 mm tool penetration, tool travel speed 0.85 mm/sec @ 1200 rpm

Strength of the DP 820 acrylic = f (temperature)

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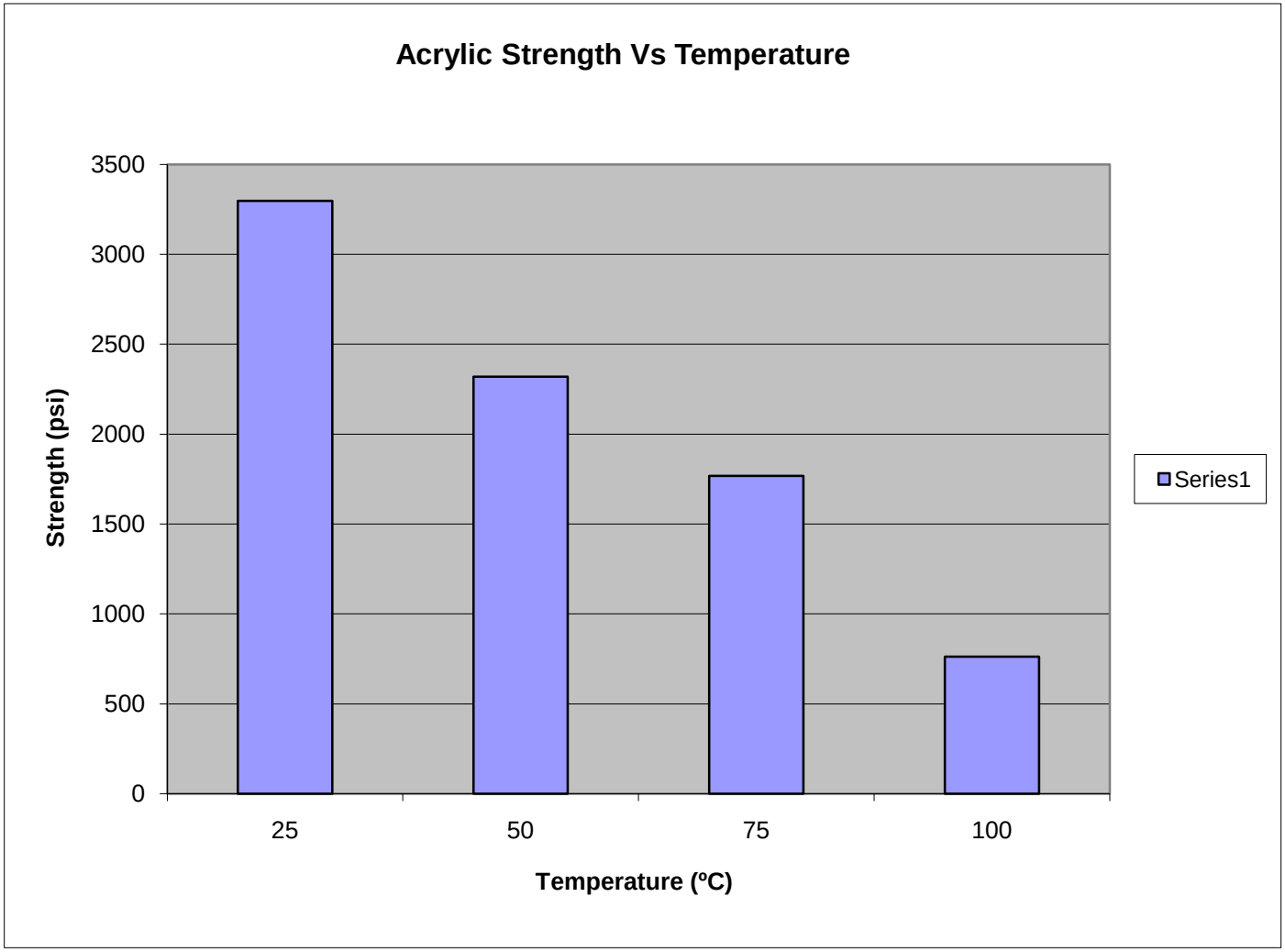

The adhesive will need to support FSW loads at a “warm” temperature

Machine Specifications (minimum)

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- Spindle Speed: 2000 RPM
- Z-Load: 8.9 kN (2000 lbf)
- Spindle Torque: 27N-m (20 ft-lb)
- Z-Axis Travel: 50 mm (2 inches)
- Y-Axis Travel: 150 mm (6 inches)
- X-Axis Travel: 1 m (36 inches)
- X- and Y-Axis Travel Speed: 250mm/min (10 ipm)

Potential Applications: Al alloy ship decking

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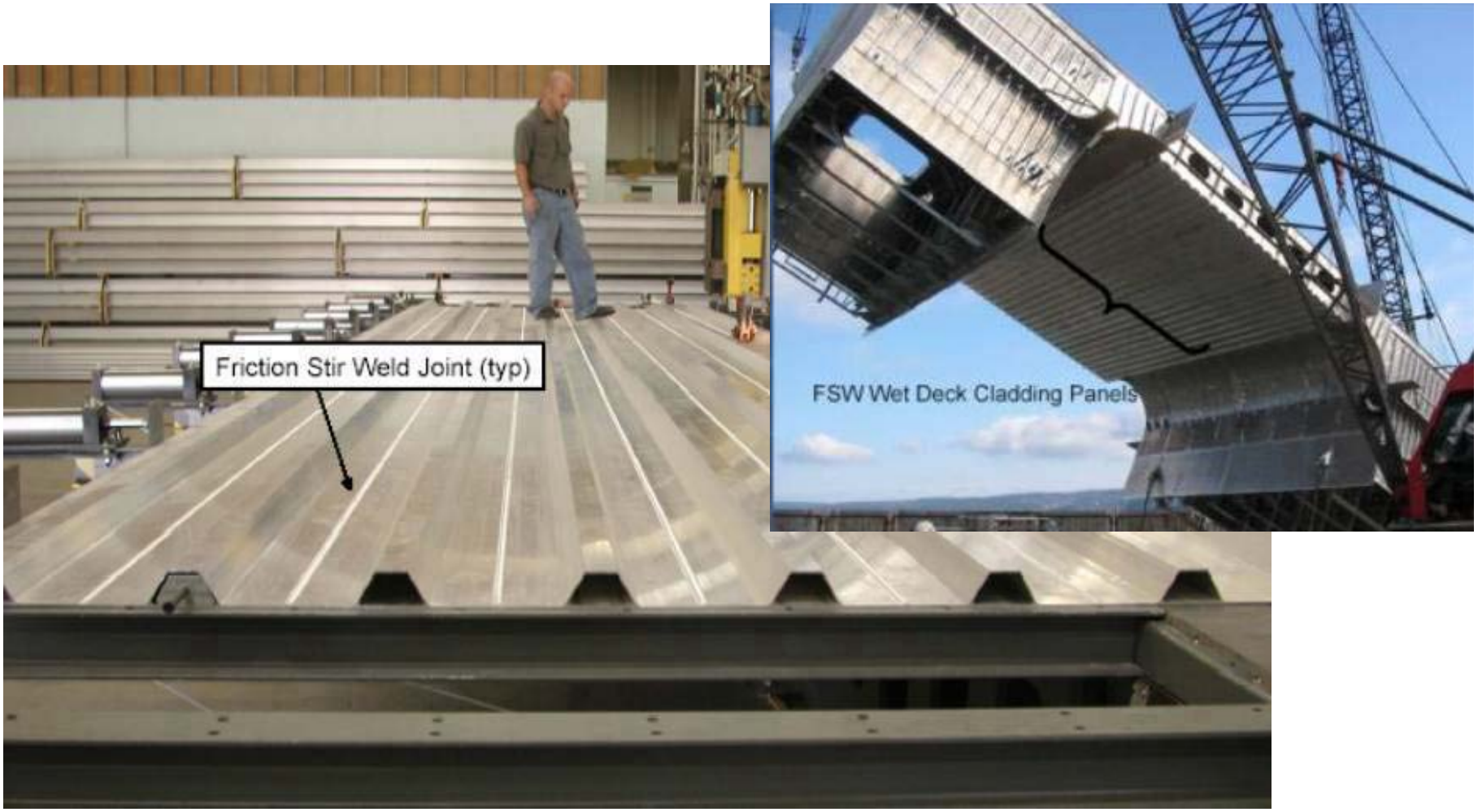

FSW Al decking for the LCS

Courtesy: AJT

Summary

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- An extremely portable, compact and versatile friction stir weld system has been defined
- The concept design is comprised of:
  - 1) track assembly (<41 kg)
  - 2) spindle carriage(<41 kg)
  - 3) spindle (<41 kg)
- Two-person assembly (no assisting equipment)
- Adhesive attachment resists expected FSW normal loads for 6mm tool penetration in AA 5083 with large safety factor
- Seam tracking to follow crack (.01 mm sensitivity)
- Capable of cutting out damaged section—FSW panel in place with sufficient anvil support
- Z-axis loads and torque were minimized with tool design and FSW parameters producing defect free welds with normal loads approaching 7.6 KN (1700 lbf)
- System being built to design specifications for prototype crack repair

Tensile Strength Procedure with Acrylic Adhesive

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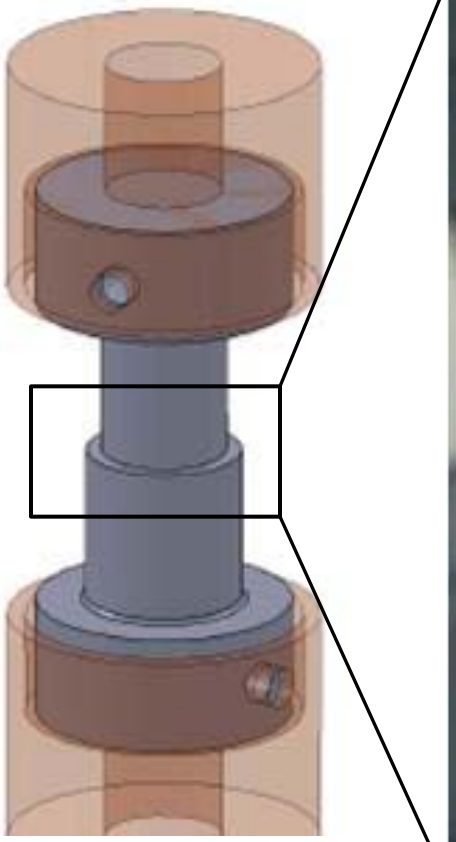

Tensile Test Assembly

Attachment Blocks Bonded with Acrylic