Friction Stir Spot Welding of Advanced High Strength Steels (AHSS)

(13056 ORNL, 13055 PNNL)

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Outline

- Purpose of work
- Barriers
- Approach
- Performance Measures and Accomplishments
- Technology Transfer
- Plans for Next Fiscal Year
- Summary

Purpose of Work

Overall Project Goal: ***To evaluate the response of Advanced High-Strength Steels (AHSS) to friction stir spot welding (FSSW) in order to promote more widespread use of AHSS to help meet weight reduction targets***

The main focus of this project is the development of the FSSW process in advanced high-strength steels of interest to the OEMs

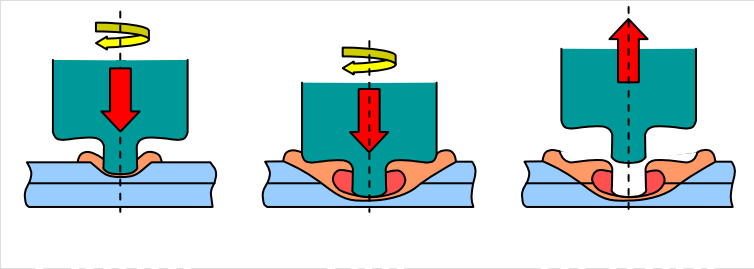
- **Specific Focus for FY07**
  1. **Establish the appropriate tool designs & materials**
  2. **Assess Joint properties, microstructures, failure mechanisms**
  3. **Establish framework of a design database for the process**

Barriers

- Increased federal mandates increasing vehicle roll over standards have led to a greater use of advanced high strength steels in structural components
  - With the increasing use of highly specialized steels, the robustness and performance of RSW is being called into question
- Performance of fusion weld joints in some advanced high strength steels is low
  - Fusion welding destroys the microstructure of AHSS, leading to coarse-grained, brittle, cast microstructure. FSSW will likely show slower cooling rates than Resistance Spot Welding (RSW), so potentially less martinsite formation (hard nuggets can lead to interfacial fracturing).
  - In some cases, FSSW shows higher ductility weld nugget region than RSW, higher energy absorption, potentially better crash performance.
- Additionally-FSSW in steels has required expensive tooling that has been considered a major barrier.

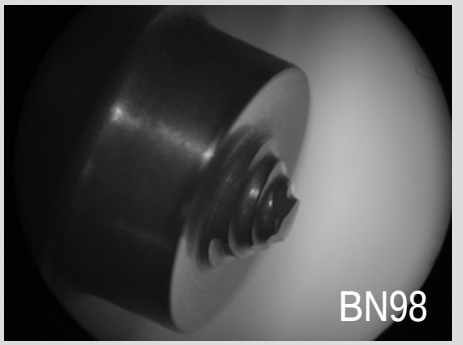
Approach – FY07

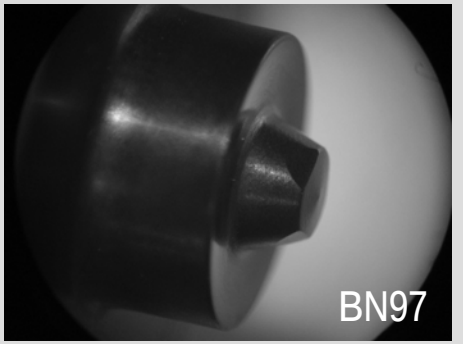
- **Produce Lap joints to correlate tensile shear strength with processing parameters and tooling**
  - **Two 1.5-mm bare steels – DP780, Hot-stamped boron**
  - **Weld Parameter Variations**
    - **2 stage Plunge at two predetermined rates**
    - **RPM, plunge rate**
  - **Total Weld Time (touchdown to extraction): 2 to 9 sec seconds**
  - **Tool Materials: PCBN, Si_3N_4, TiB_2**

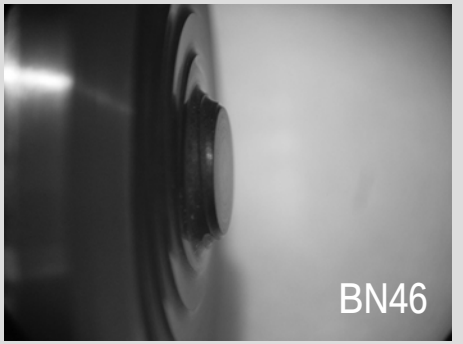


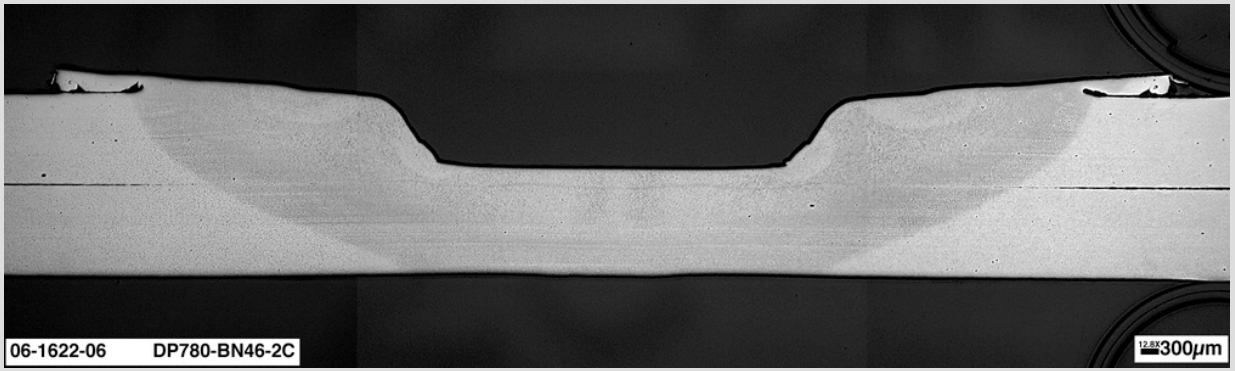
Performance Measures and Accomplishments

- Developed FSSW parameters to successfully produce numerous welds at various conditions above the AWS D8.1M RSW minimum specification.
  - Detailed microstructure, hardness and tensile data for various conditions
- Implemented several new tool materials and designs that effectively reduced process loads and tool cost.
- Constructed a process database for FSSW of advanced high strength steels.



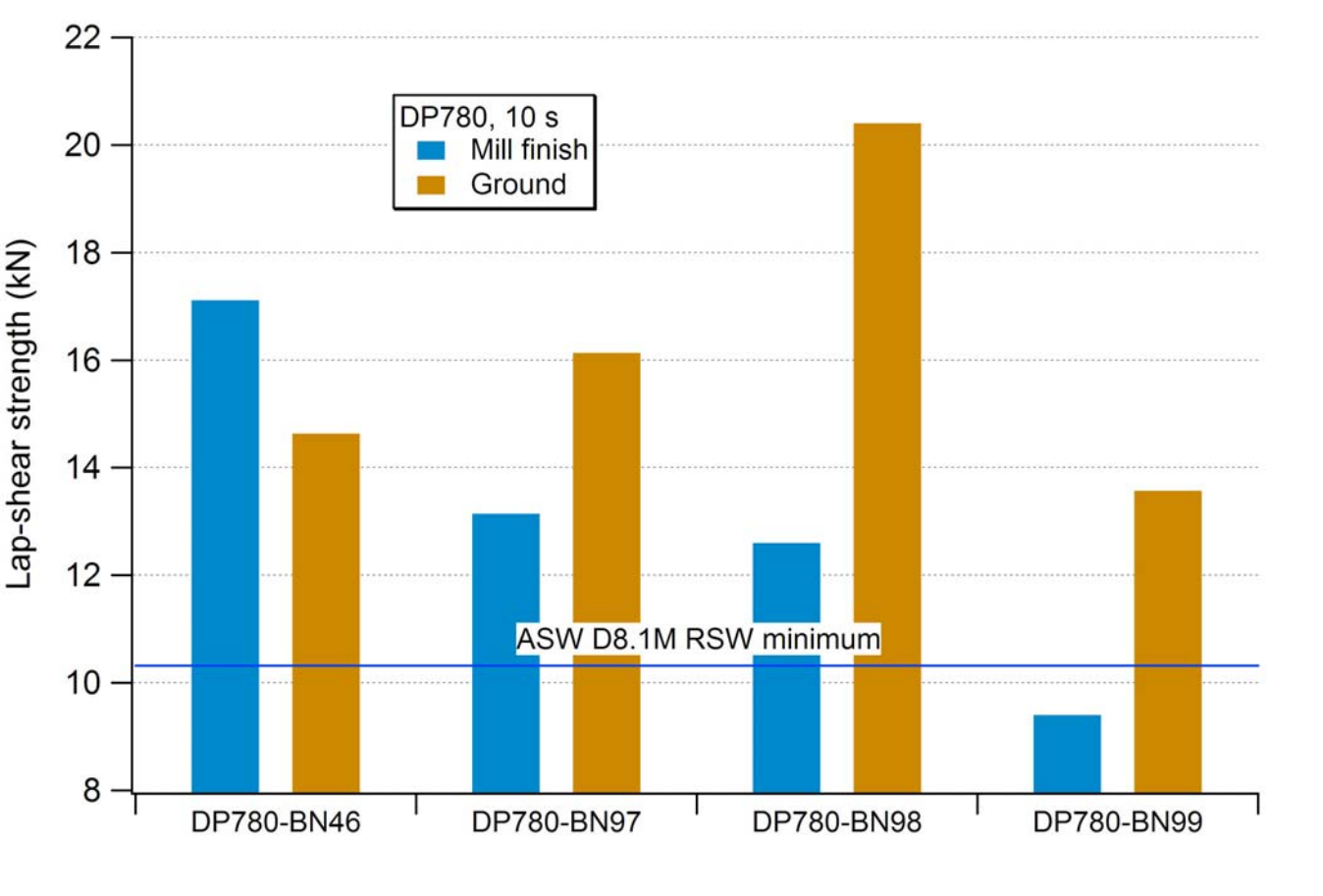






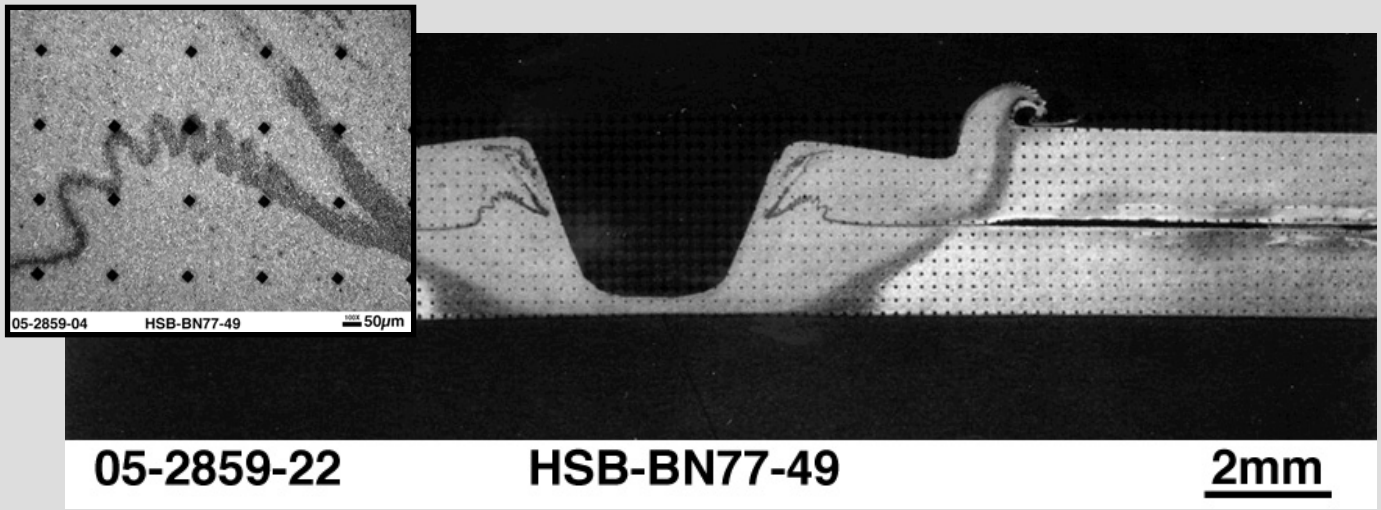
Performance Measures: Tool Design

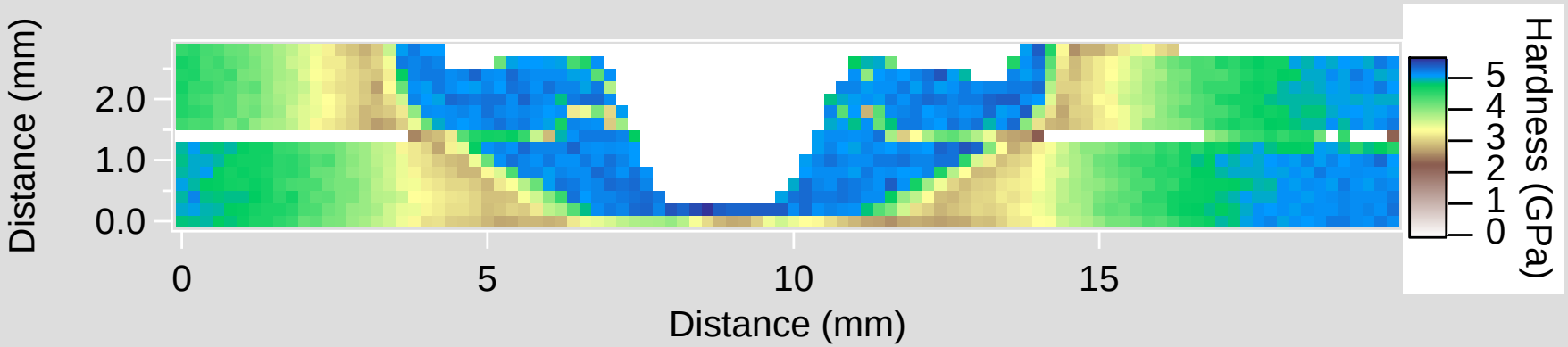
BN46 in PCBN



- Phase 2 tools producing joint strengths in excess of ASW D8.1M RSW minimum

Accomplishments: Weld Characterization & Failure Analysis





Technical Accomplishments: New Tool Materials

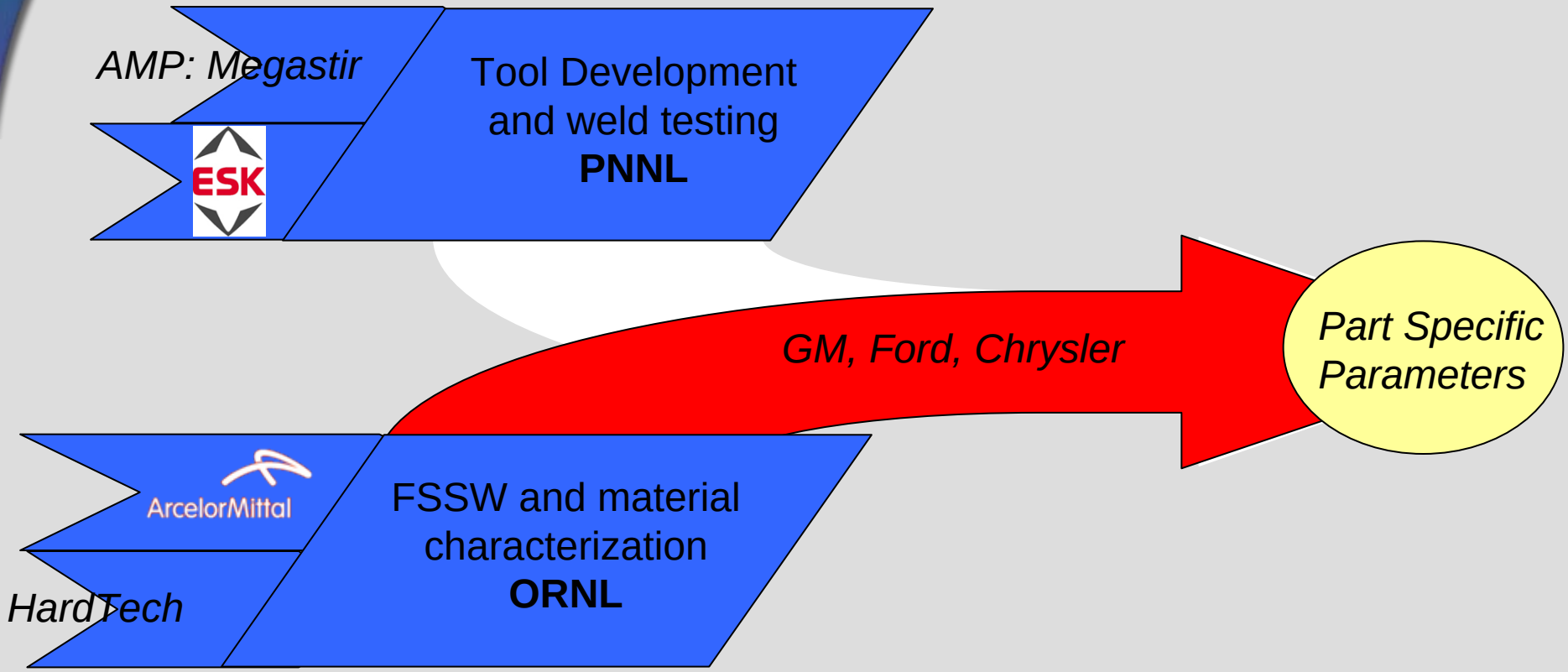
- 97 tool shape was reproduced in two new materials: Si_3N_4 & TiB_2
- These tool materials are less than one quarter the price of PCBN

- Joint strengths are comparable for Si_3N_4 and PCBN

- Machine Loads are reduced by more than 25% for Si_3N_4 over PCBN

Technology Transfer

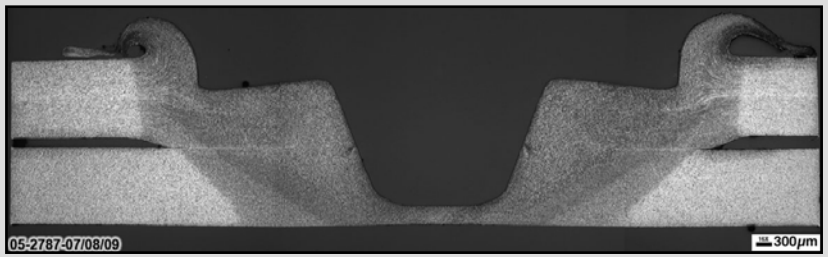
- Collaboration of PNNL, ORNL, OEMs and Suppliers



Plans for the Next Fiscal Year

Next phase of project will begin to establish "process robustness", operating window, statistical information on failure probability

- Tool designs will be finalized and wear and durability studies of selected tools will begin
  - Final deliverables will include information on both statistical joint performance with tool design, and on tool material durability.
- Additional studies planned for FY08 include:
  - Evaluate the effects of stirring through coatings (HDG/Galvaneal/other)
  - Process modeling with weld performance prediction
  - Establish framework of a design database for structures (minimization of flange width, effect of multisheet stack up)



Summary of Activities

- Hundreds of welds made
  - Data has been accumulated on the effects of weld time, rpm, tool shape on appearance, bonding, fracture, microstructures, properties, and process loads
  - Wear rates on PCBN, when operated within appropriate conditions, are very low
- New tools have been redesigned, fabricated, and testing is underway
- Spot welds of high shear tension strength (up to 16 kN) were obtained with redesigned tools
  - Strengths compare favorably with minimum of AWS D8 draft RSW standard
- Welding times less than 4 s are feasible
- Lower cost tool materials are being evaluated and some are showing promise

FY07 Publication:

Y. Hovanski, M.L. Santella, G.J. Grant. FSSW in Hot-Stamped Boron Steel, Scripta Materialia 57 (2007) 873-876.