Friction Stir Welding of Dual Phase Steel

Tracy W. Nelson and Carl D. Sorensen

Department of Mechanical Engineering

Brigham Young University

Provo, UT

Russell Steel and Scott Packer

MegaStir Technologies

Provo, UT

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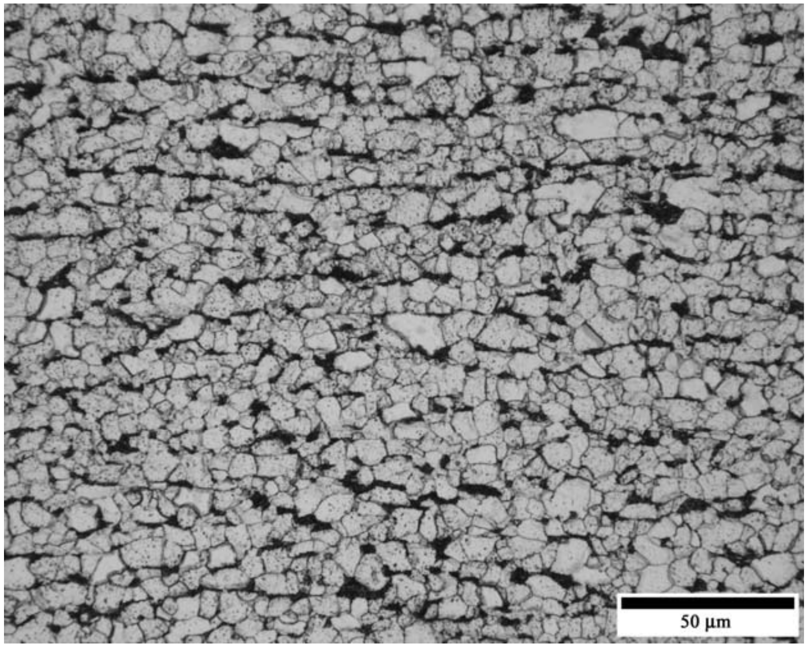
Outline

- Background
  - Very little
- Approach to FSW of Dual Phase Steel
  - Material
  - Equipment
  - Tool and parameters
- Results
- Summary
- Future work

Dual Phase Steel

- Sheet material developed for automotive
  - Microstructure consisting of ferrite and small islands of martensite
  - Improved strength with excellent formability
- Difficulty maintaining microstructure during fusion welding
  - Laser welding produce much more martensite
    - Centerline cracking may occur either during welding or forming



Approach

- Dual Phase Steel (Dual Ten™ 590)
  - Thickness: 5.5 mm (0.215 in)
  - Partial and full penetration butt welds were produced
- Process Parameters
  - RPM 450-550
  - Feed Rate 12.7-24 cm/min (5-9.5 ipm)
  - Lead angle 3°
  - Shielding gas Argon@23.6 l/min (40 cfh)
  - Initial weld run in displacement control
  - Subsequent and full penetration welds run under load control 3,800-4,500 Kg (8,500-10,000 lbf)

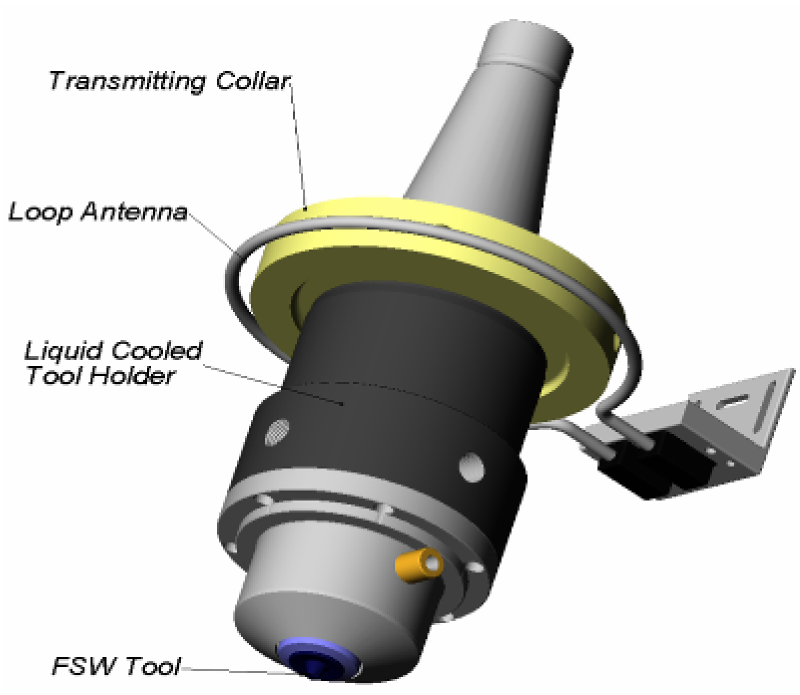
Approach

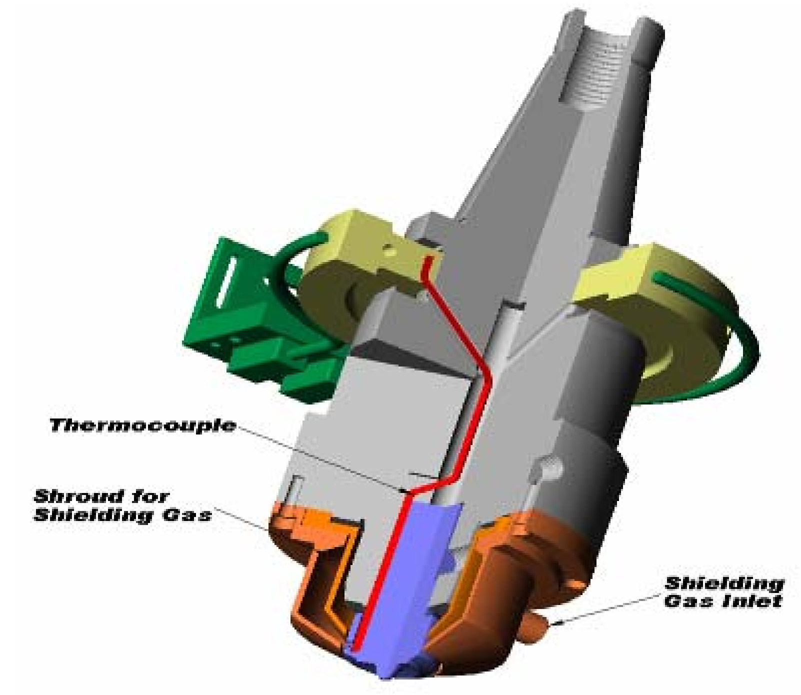
- Poly Crystalline Cubic Boron Nitride (PCBN) Tooling
  - Tool Geometry
    - 25 mm (1”) diameter shoulder
    - Initial pin tool length was 4.5 mm (0.175 in)
    - Subsequent full penetration welds made with 5 mm (0.20”) pin tool length
    - Three flats on pin tool

MegaStir TECHNOLOGIES

FSW Equipment

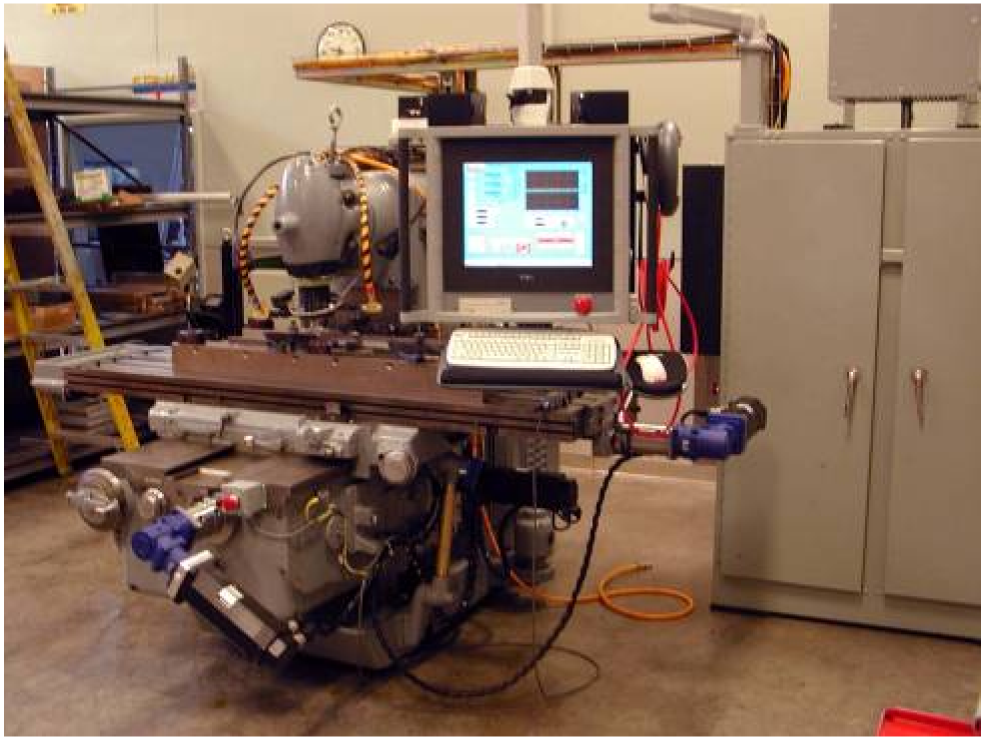
- Liquid cooled tool holder and telemetry system





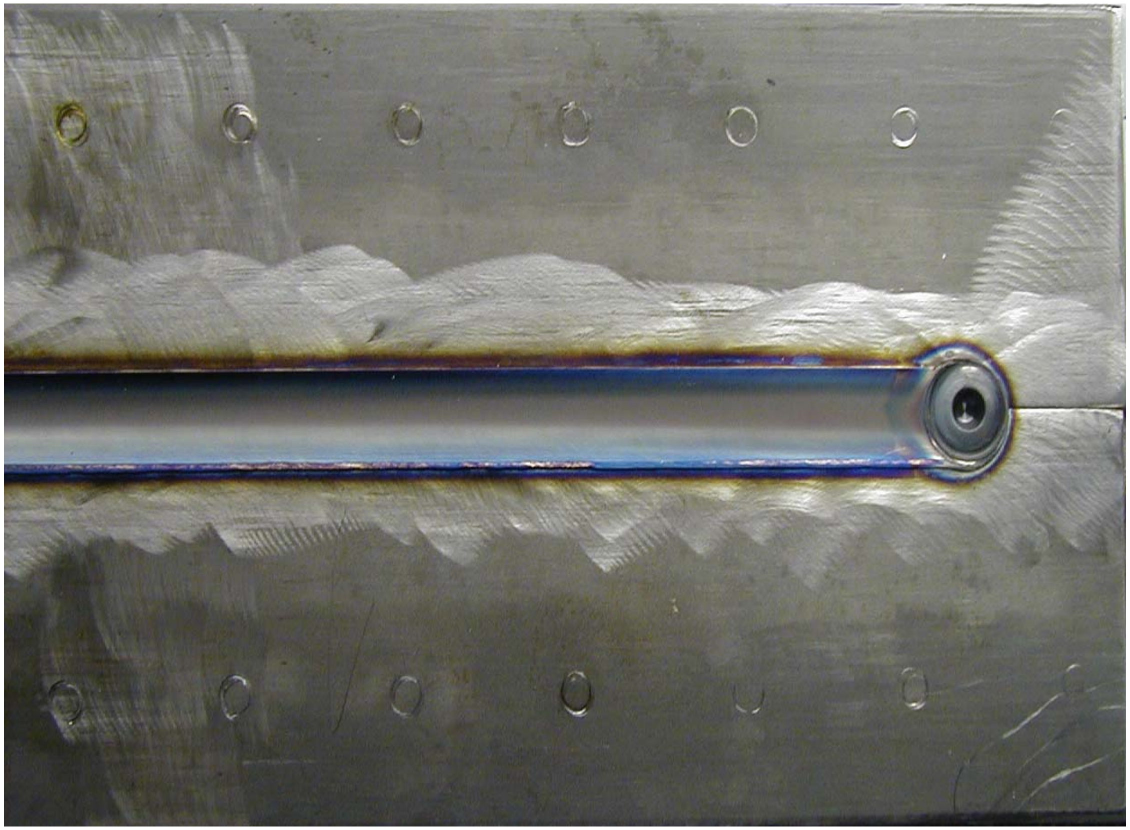
FSW Equipment

- Equipment and software design by Megadiamond Sii and BYU
- System designed for research environment



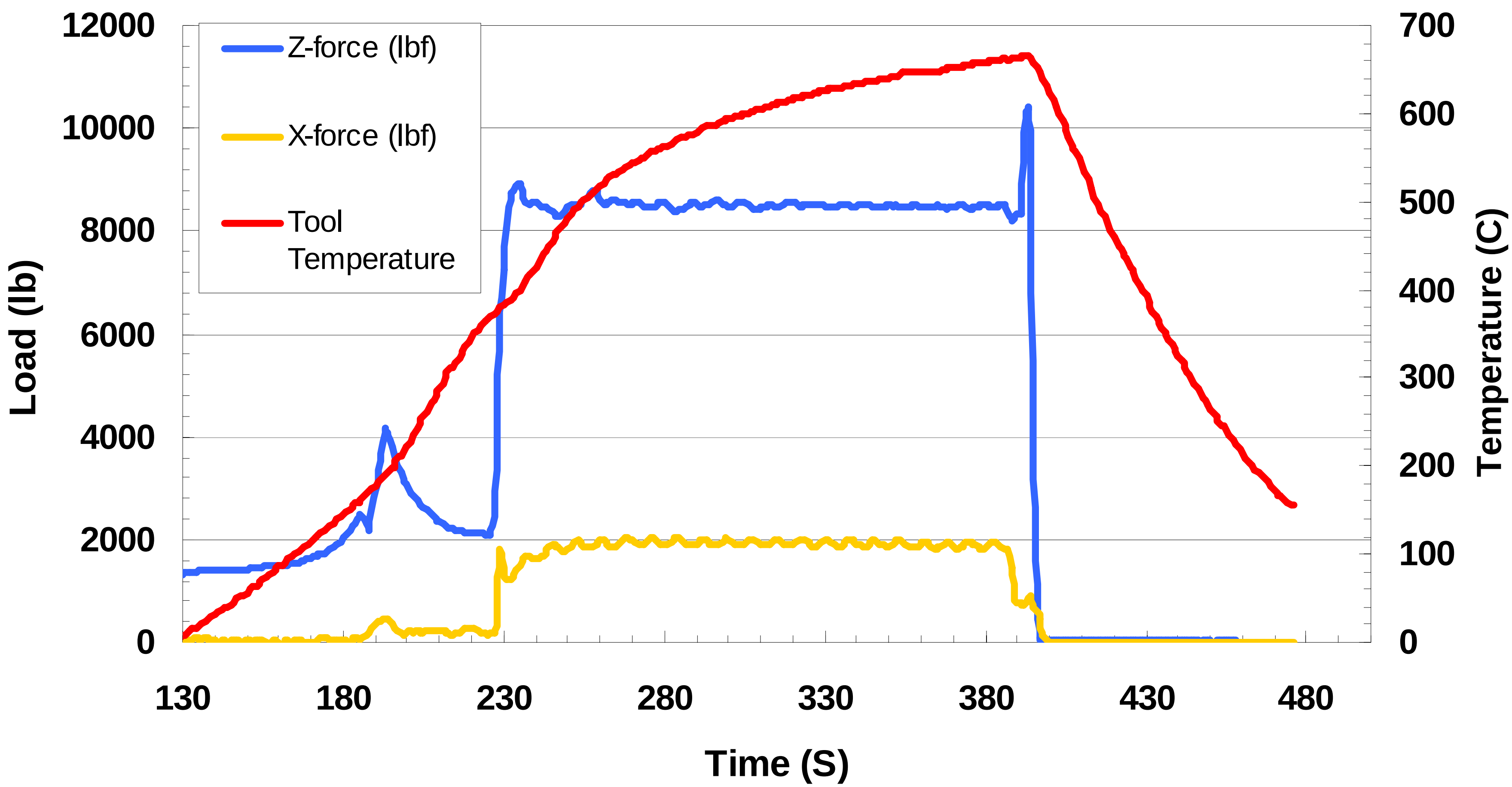
Results

- As-welded appearance was excellent
- Limited distortion on 60cm (2') panels



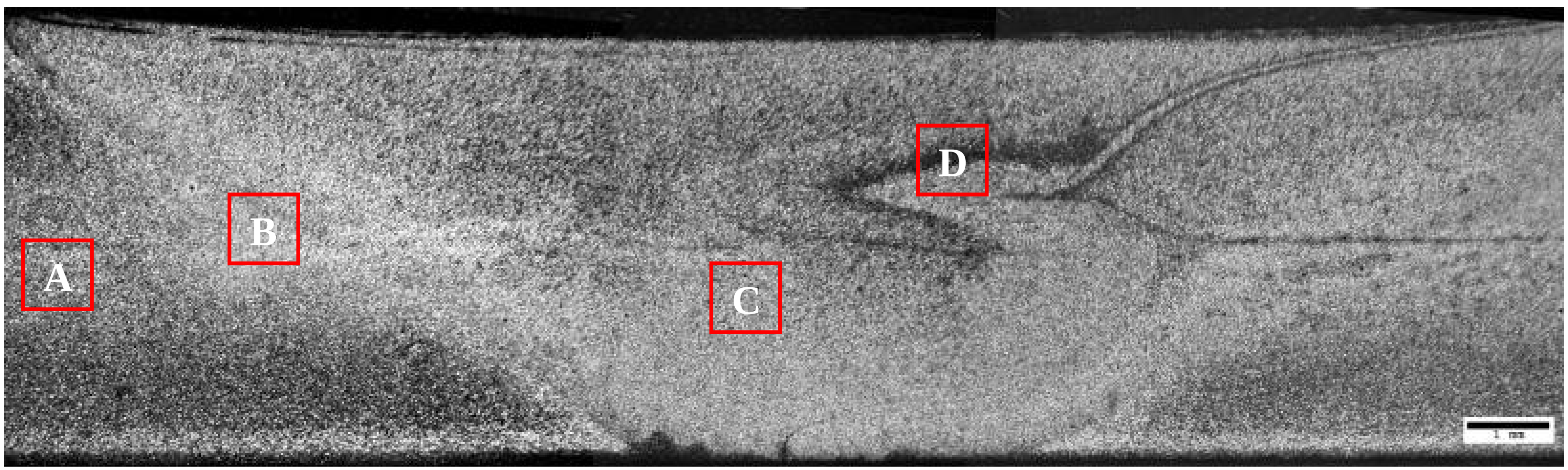
Results

- Process Parameter Data



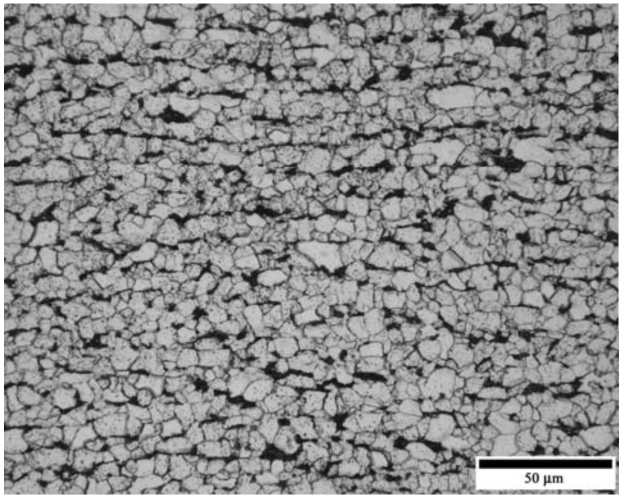
Weld Microstructure

- Cross section of FSW in Dual Ten™ 590
  - No LOC present

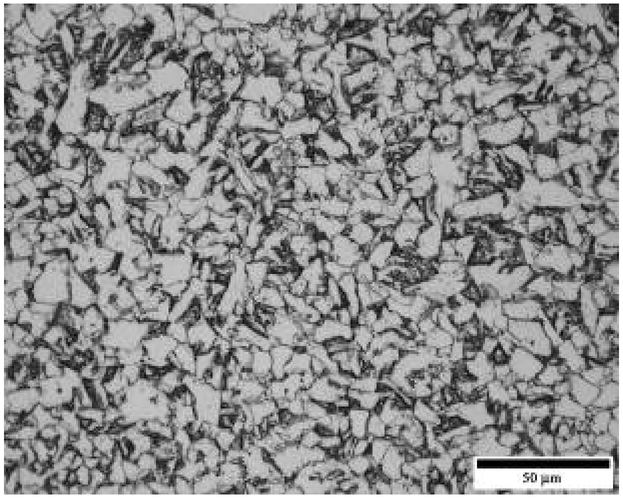


Weld Cross Section: 550 RPM, 13 cpm (5 ipm)

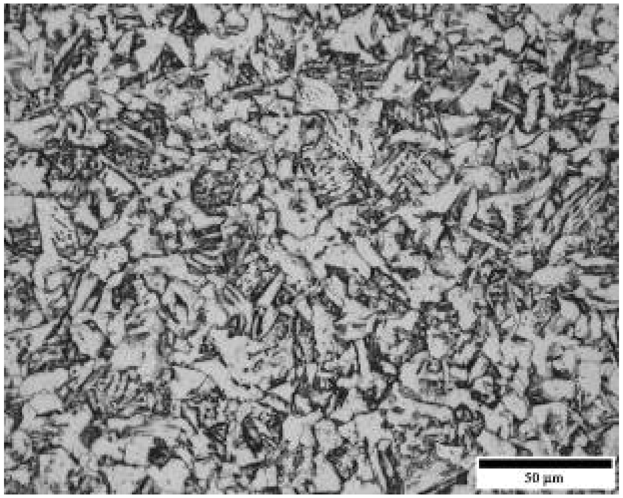
Evaluation of Weld Microstructure



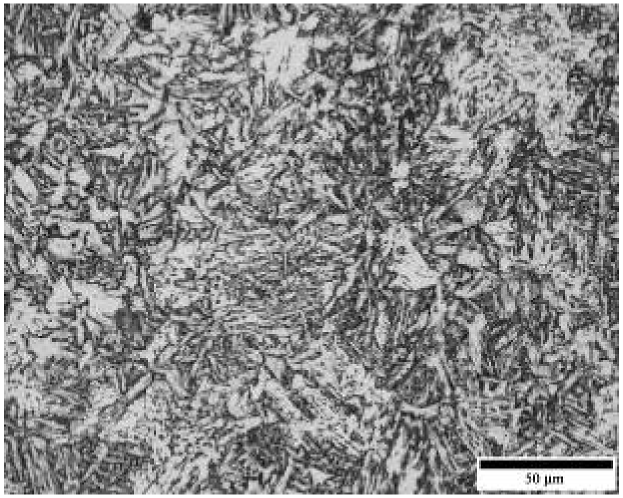
Base Metal: polygonal ferrite with colonies of martensite



TMAZ: polygonal ferrite, martensite islands are coarsening and transforming to ferrite and carbide



DXZ: ferrite/acicular ferrite (bainite) with some pearlite



DXZ-Banded Region: Accicular ferrite (bainite) with pearlite

Microhardness Comparison

- Microhardness at the various microstructurally distinct regions

Location	Average Hardness (Vickers 100 g. load)
A Base Metal	201
B TMAZ (Thermal Mechanically Affected Zone)	264
C DXZ (Weld Nugget)	291
D DXZ Banded Region	342

Mechanical Properties

- As-welded transverse tensile properties were very good
  - Very little loss in elongation
    - Maintained fine grained microstructure

Dual Phase Steel FSW			
Weld Parameters rpm/cpm(ipm)	**Yield Strength KSI (Mpa)**	**Tensile Strength KSI (Mpa)**	**Total Elongation (%)**
450/16.5(6.5)	71 (489)	103 (710)	24
450/21.6(8.5)	70 (482)	102 (703)	20
450/24(9.5)	72 (496)	103 (710)	22
Base Metal *	49 (340)	86 (590)	25

* as reported in literature

Formability Test Results

- Preliminary formability studies are promising
  - Plane-strain formability of the welded specimens was about the same as that of the base material
  - Biaxial tension the welded specimens were much less formable
- More formability characterization needed!!
  - Need to explore effects of FSW parameters and tool design on formability
  - Dissimilar weld combination should also be explored
  - Further grain refinement

Material	Test	Failure Height (mm)
Base D-P Steel	OSU Plane-Strain	34.3
FSW D-P Steel	OSU Plane-Strain	36.1
Base D-P Steel	Full Dome Biaxial	34.6
FSW D-P Steel	Full Dome Biaxial	22.2

Summary of FSW/P of HTM

- Fully consolidate welds were produced in Dual Phase steel over a wide range of welding parameters
- As-welded tensile properties were excellent
- Initial formability data was promising
- PCBN tools showed **no evidence** of tool wear

Future Work

- Continue research for FSW of this material
  - Determine process window/maximum travel speeds
  - Microstructure and properties as a function of process parameters
  - Evaluate potential to refine grain within the weld nugget
- Formability studies/comparison
  - Preparing program to evaluate formability as a function of weld parameters
  - Compare formability with other welding processes