

Friction Stir Welding of Alloy 600

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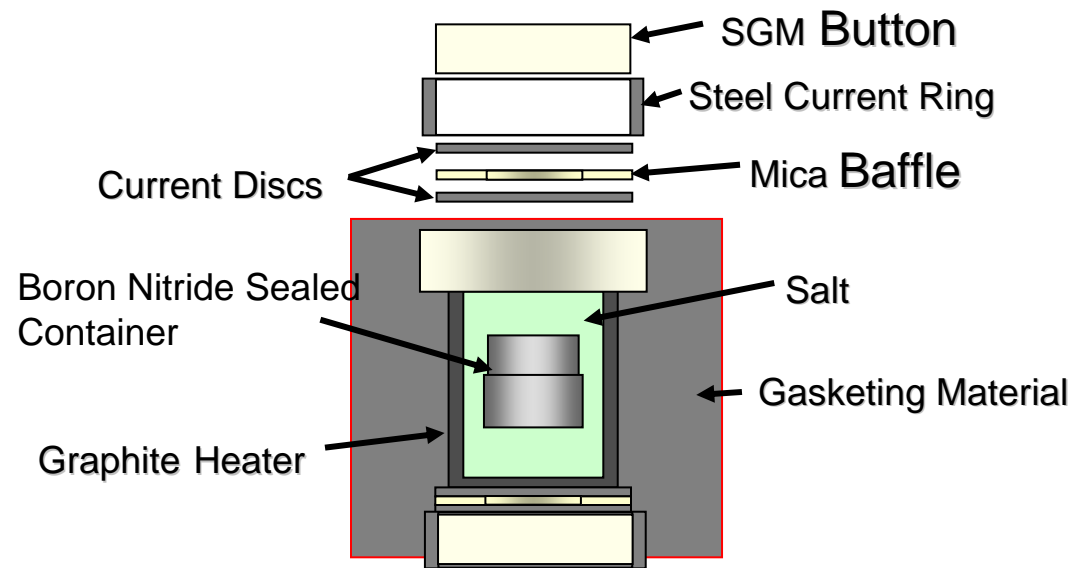
Presentation Topics

- PCBN Tooling Overview
 - Tool Material and Design
 - Tool holder and Telemetry system
- Experimental Approach
- Results and Discussion
- Summary



Polycrystalline Cubic Boron Nitride (PCBN)

- Second in hardness only to diamond
- Diamond crystal structure, with N and B occupying alternate lattice sites
- CBN powder created in HT-UHP presses (1700 K, 6,000 MPa)
- CBN powder sintered in HT/UHP press to form polycrystalline blank

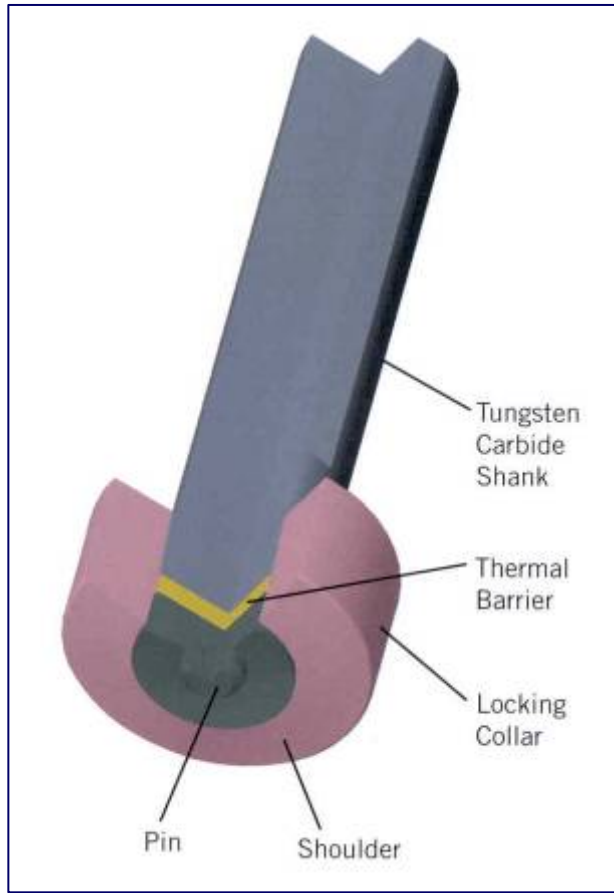


PCBN Properties

- Hard, wear resistant, survives temperatures to 1500 K
- Chemically inert
- High tensile strength, low toughness
- Difficult to manufacture
- Limited to relatively small pieces
- High thermal conductivity



Specific Tool Design



- 19 mm WC shank
- 19-25 mm ϕ CBN disk
- 6° face angle
- Pin L/D about 0.5
 - Lengths up to 6 mm
- Radii about 1 mm
- Pin
 - Smooth for short pins
 - Flats on end for long pins



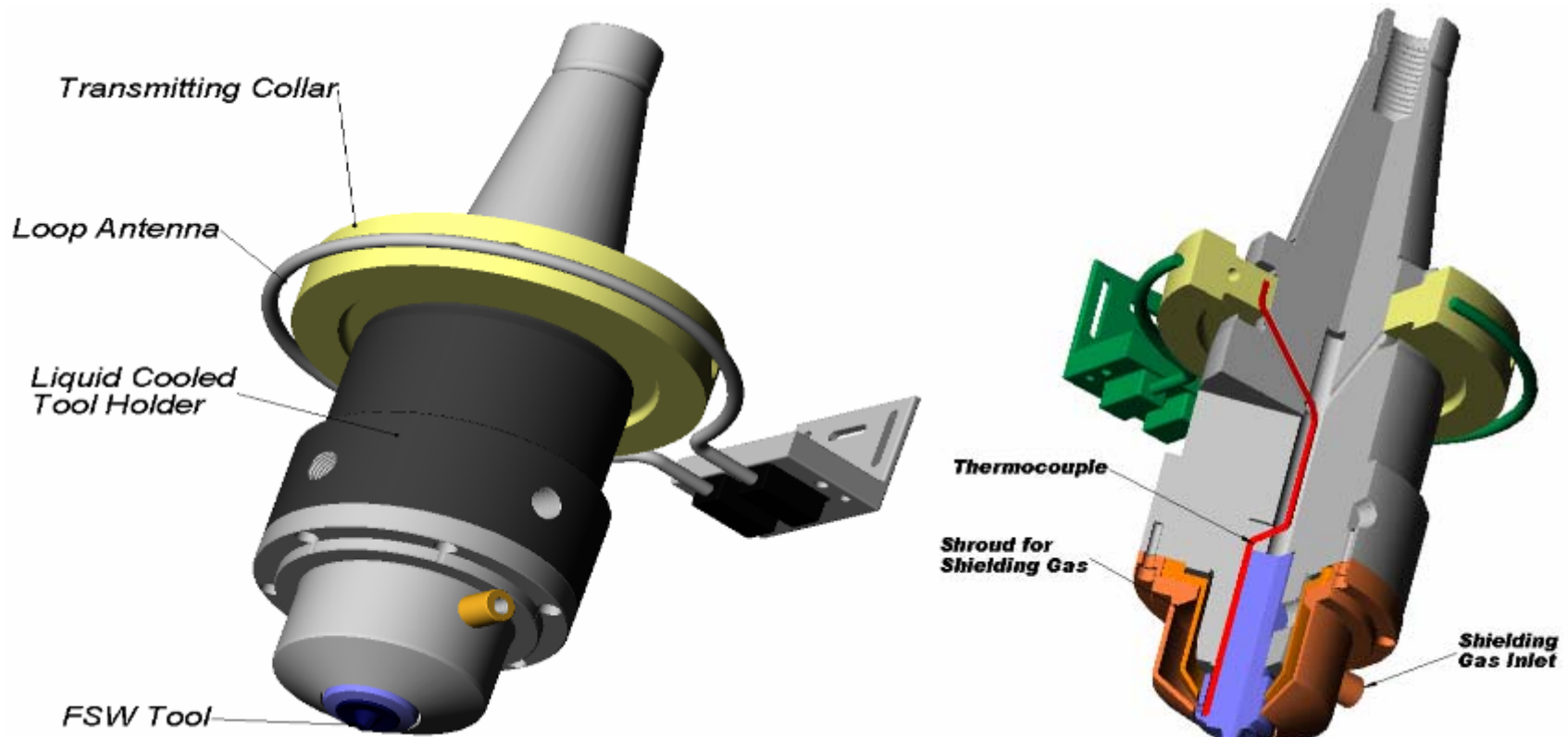
Tecnara™ Tool Holder



- Chilled water-glycol recirculator on shank
- Fits in milling machine (#50 Taper)
- Instrumented for tool temperature
- Very low runout -- 0.005 mm (0.0002") at 20 cm (8") below holder
- Air/gas cooling on locking collar



Tool Holder and Telemetry



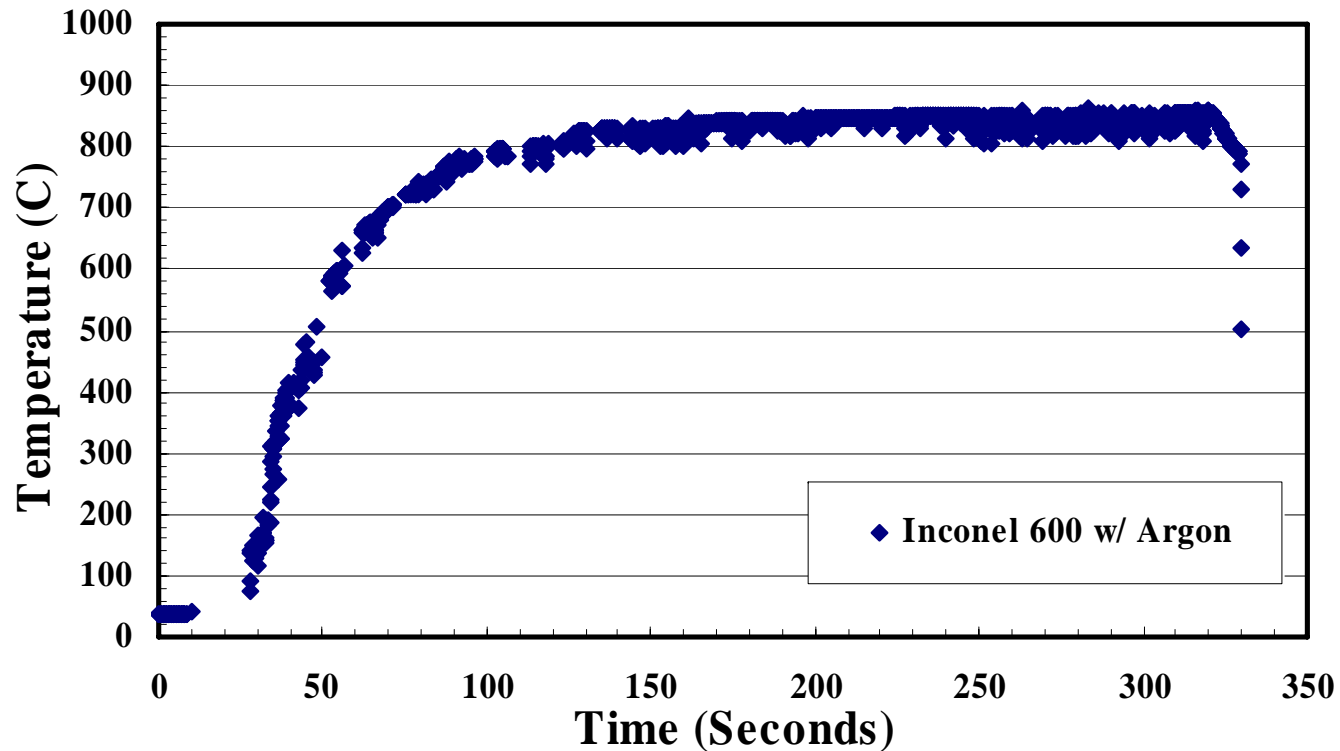
Experimental Approach

- 4 mm thick alloy 600
 - (72 min. Ni+Co, 14-17Cr, 6-10Fe, 0.15 max C, etc.)
- PCBN FSW tool
- FSW parameters
 - 446RPM 2 ¼ IPM
 - 600 RPM 2 ¼ IPM
 - 446 RPM 2 ¼ IPM w/ Argon Atmosphere
- Resulting weld properties and quality
 - Tensile testing in accordance with ASTM E8
 - Microhardness V-100g
 - Transverse metallographic samples



Thermal Profile of Tool

- Thermal Cycle measured off of the OD of PCBN



FSW in Alloy 600

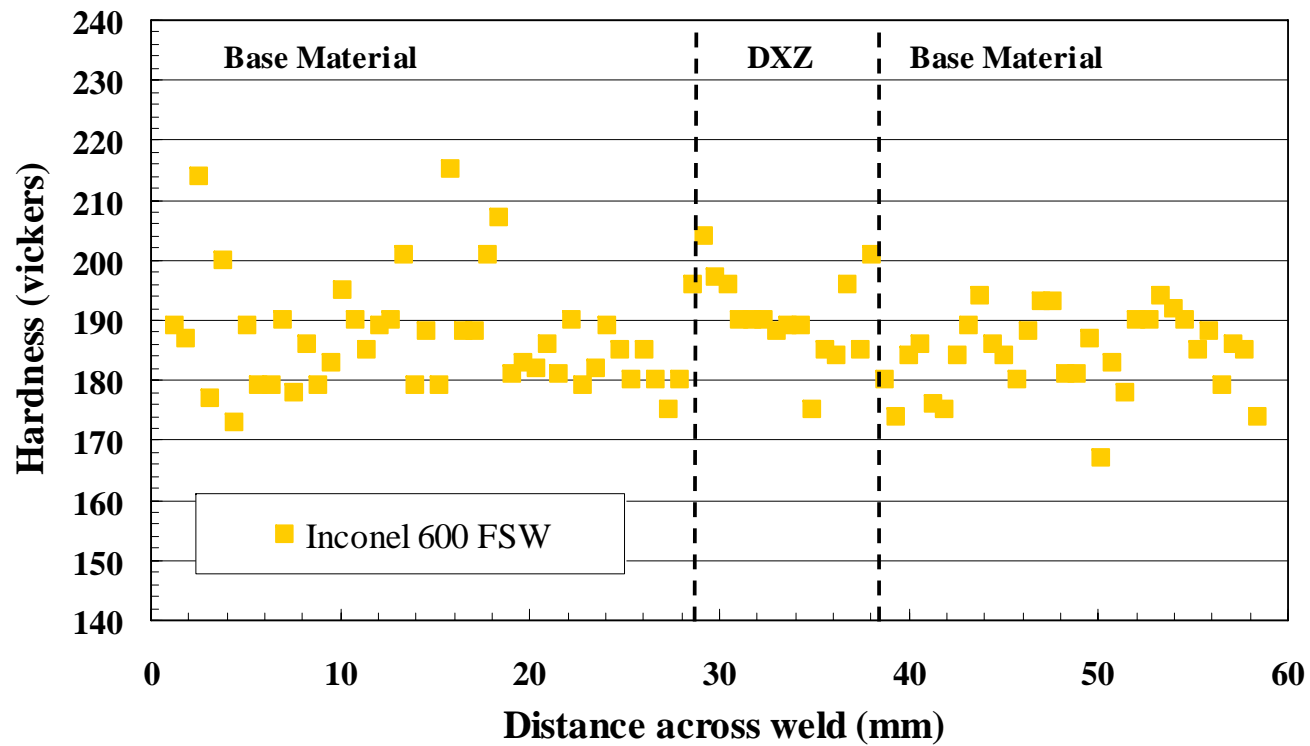


Transverse Weld Tensile Properties

Inconel 600 FSW			
Sample	Yield Strength 0.2 % offset MPa(KSI)	Ultimate Tensile Strength MPa(KSI)	Elongation %
<i>446RPM 2 ¼ IPM</i>	<i>374 (54.3)</i>	<i>727(105.5)</i>	<i>30.8</i>
<i>446 RPM 2 ¼ IPM w/ Argon Atmosphere</i>	<i>356(51.6)</i>	<i>719(104.2)</i>	<i>28.6</i>
<i>600 RPM 2 ¼ IPM</i>	<i>342(49.6)</i>	<i>698(101.2)</i>	<i>32.3</i>
<i>Base Metal</i>	<i>263 (38.1)</i>	<i>631(91.5)</i>	<i>49.8</i>

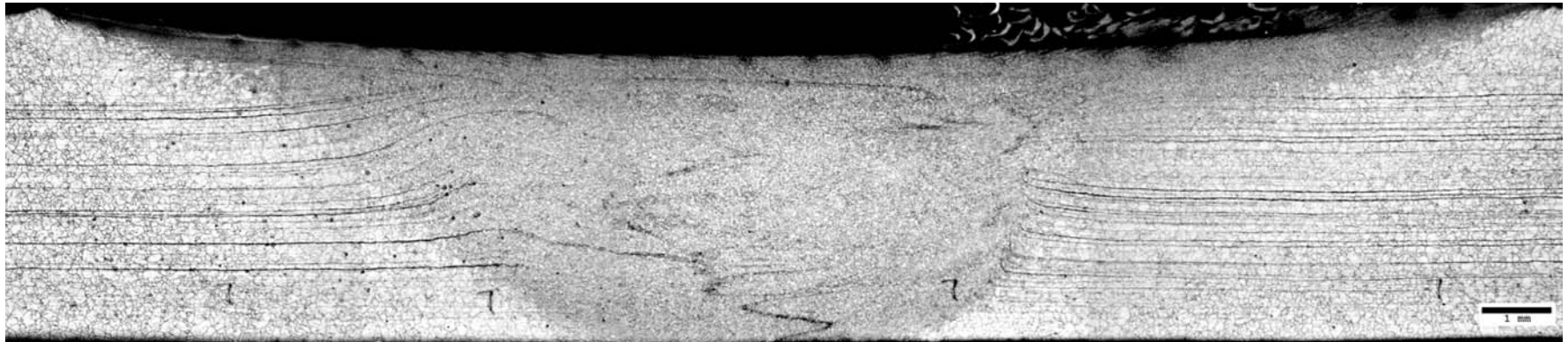


Microhardness Results

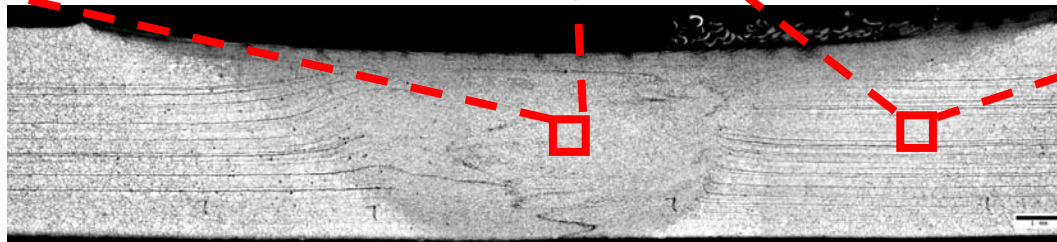
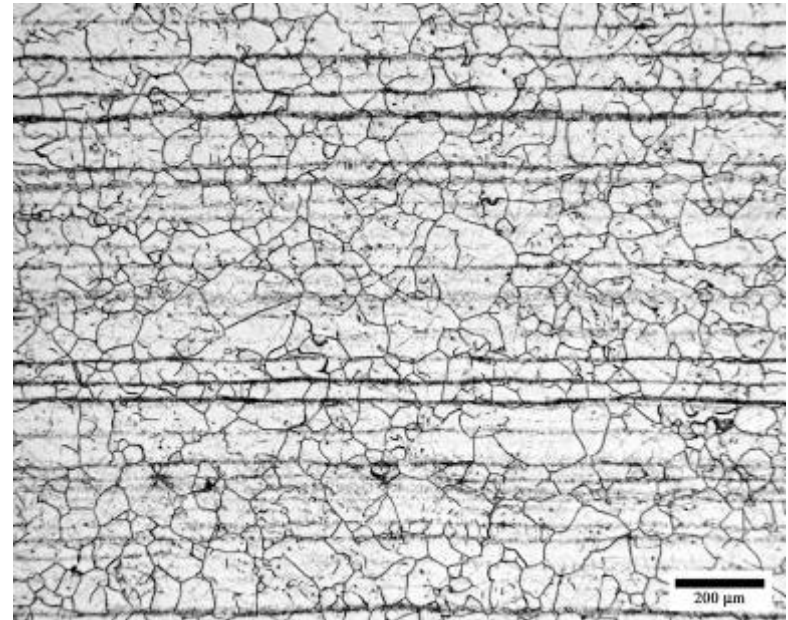
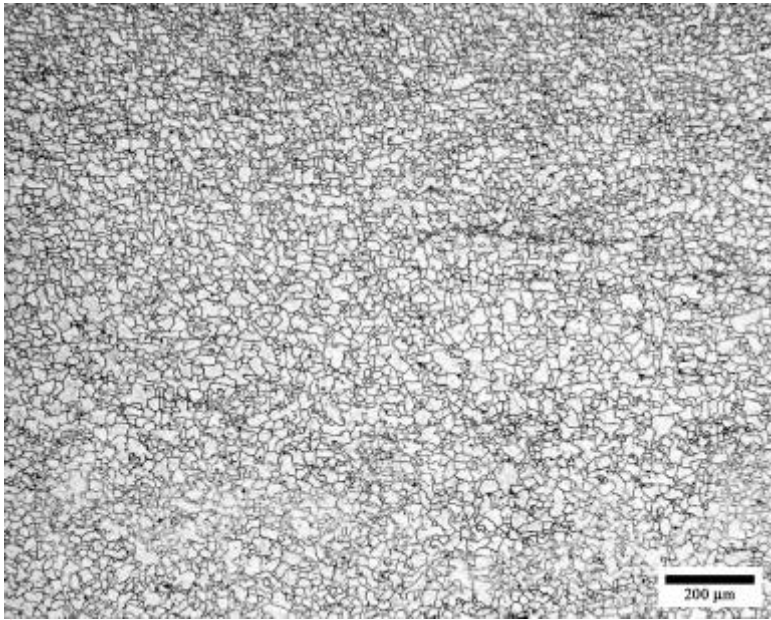


Metallographic Results

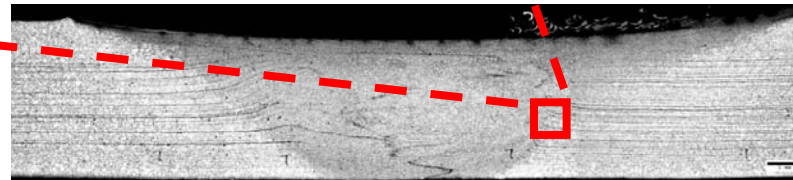
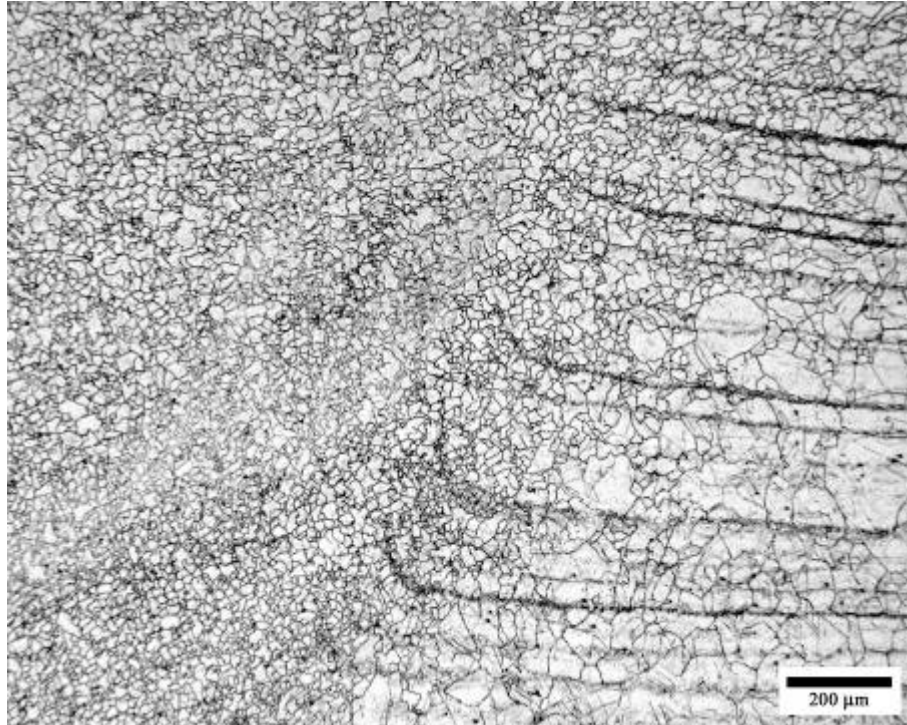
- Tool was 0.75 mm short of thickness
- Weld is fully consolidated
- Excellent flow under the pin tool

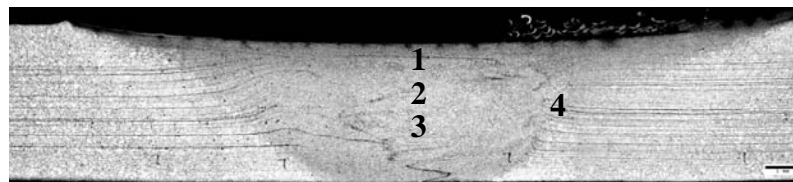
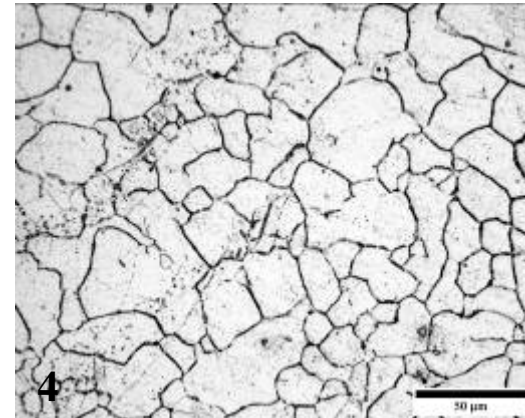
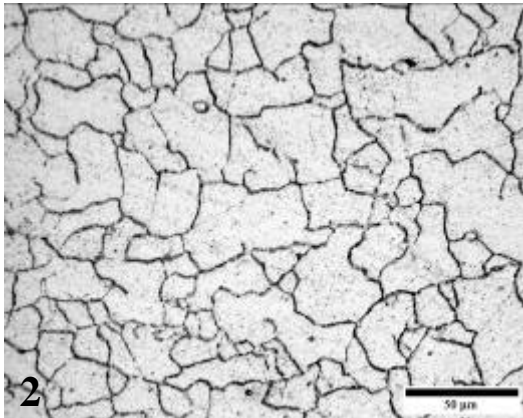
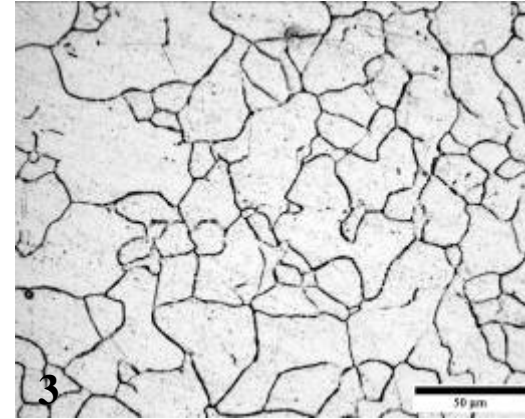
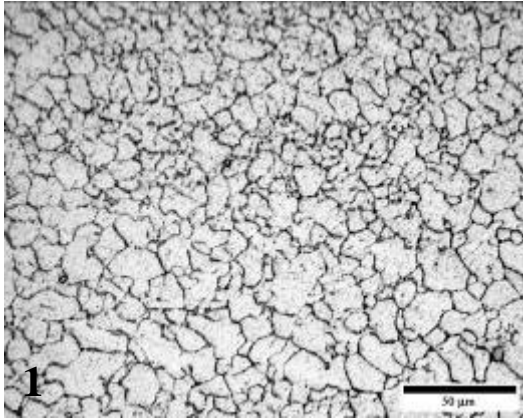


Comparison of Microstructure



TMAZ Microstructure





Tool Wear-- Before and After



Summary

- IN 600 can be successfully FSW using PCBN Tooling
 - No evidence of defect in weld
 - Evidence of good material flow around pin tool
- PCBN tool showed no evidence of tool wear in limited use, i.e. 6 feet of welding
 - Present tool life in 304L exceeds 75 feet
 - PCBN tooling can sustain temperatures in excess of 900°C
- Properties of the resulting weld exceed the base metal mechanical properties

