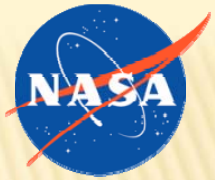
7th INTERNATIONAL EWI/TWI SEMINAR ON JOINING AEROSPACE MATERIALS



CHARACTERIZATION OF THE ULTRASONIC STIR WELDING (USW) PROCESS

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AGENDA

- Process description
- Chronology of USW
- Current USW system and capabilities
- Current process development/test results
- Future work
- Conclusions

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WHAT IS USW?

- A solid state weld process consisting of an induction coil heating source, a stir rod, and a non-rotating containment plate
- High Power Ultrasonic (HPU) energy integrated into non-rotating containment plate and stir rod
- Independent control of heating, stirring and forging pressure control
  - NASA owned IP - U.S. Patents
    - 7,568,608 “USW Process and Apparatus”
    - 8,393,520 “Pulsed Ultrasonic System”
    - 8,393,523 “Pulsed Ultrasonic Method”

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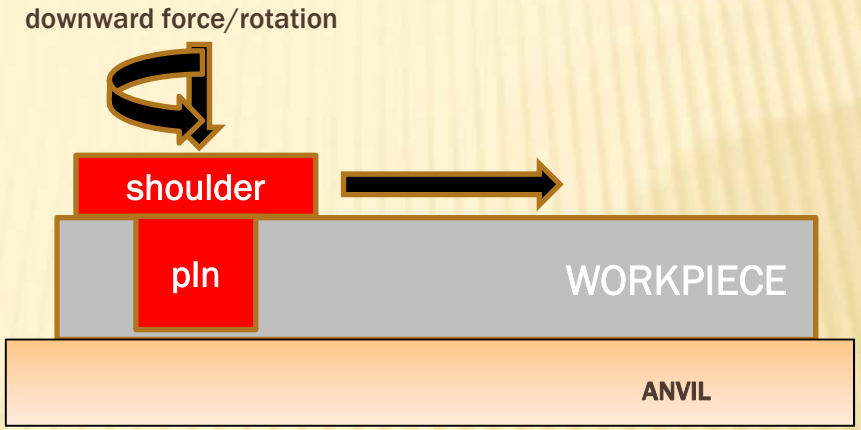
PROCESS DESCRIPTION

FSW:

Both shoulder and pin rotate together

Material is heated by frictional energy & deformational heating around pin

Cannot decouple heating, stirring, forging



USW:

Only the stir rod rotates

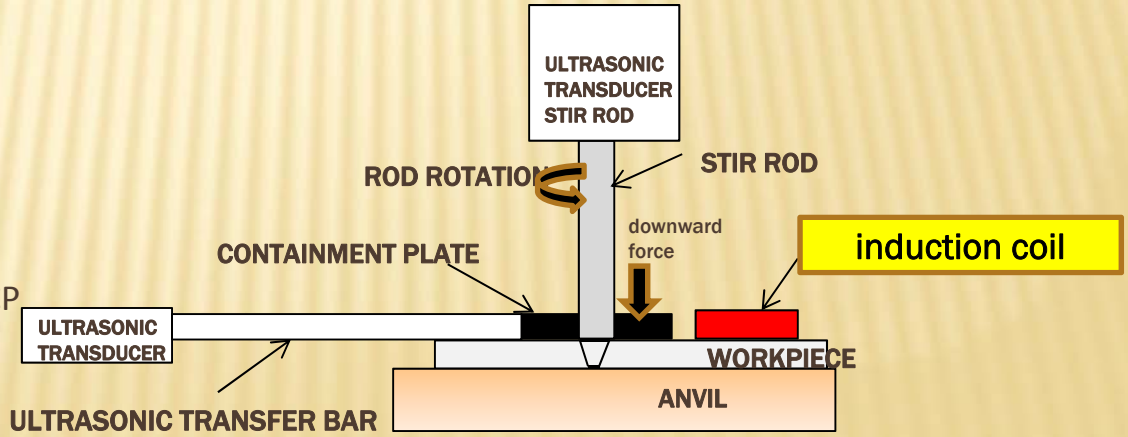
Containment plate stationary

Induction coil heats the material

Additional heat is provided by material deformation around the pin

Ultrasonic energy integrated into stir rod and CP

DECOUPLE heating, stirring,forging and Control each independently



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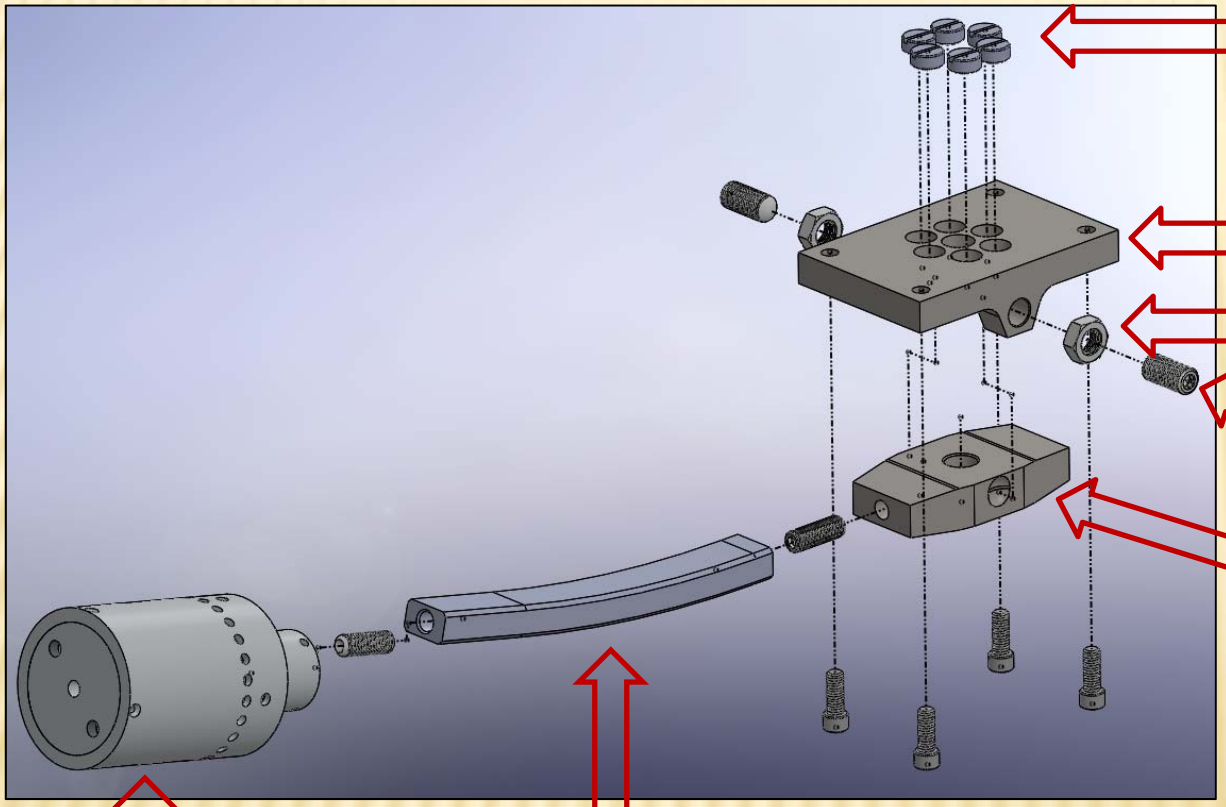
Ultrasonics - Containment

Containment – A-2 steel



Bearings

Saddle Plate

Lock Nut

Location Screw

Containment Plate

Transducer

Transmission Line

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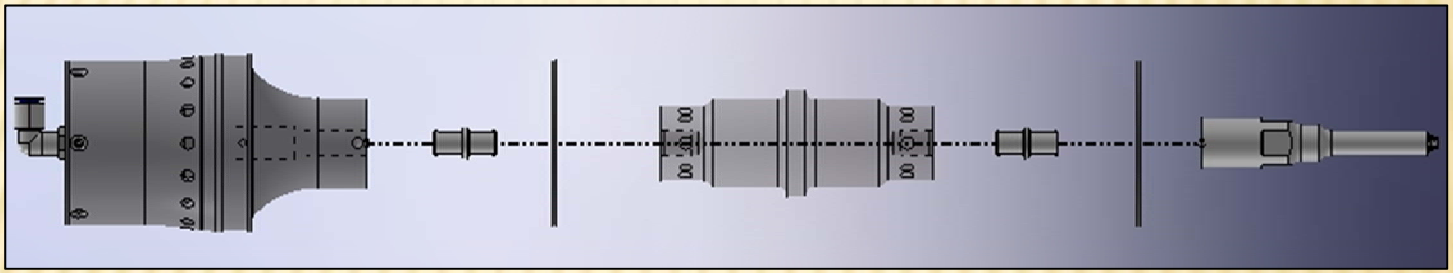
Ultrasonics - Spindle

Stir Rod – 350 marage steel



Transducer

Diaphragm Spring

Booster

Diaphragm Spring

Spindle Sonotrode

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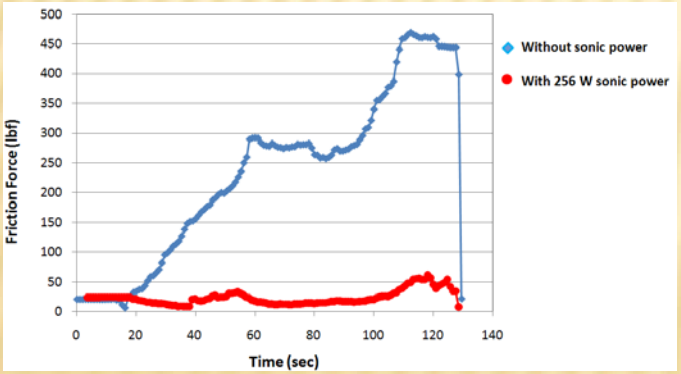
USW PROCESS CHRONOLOGY

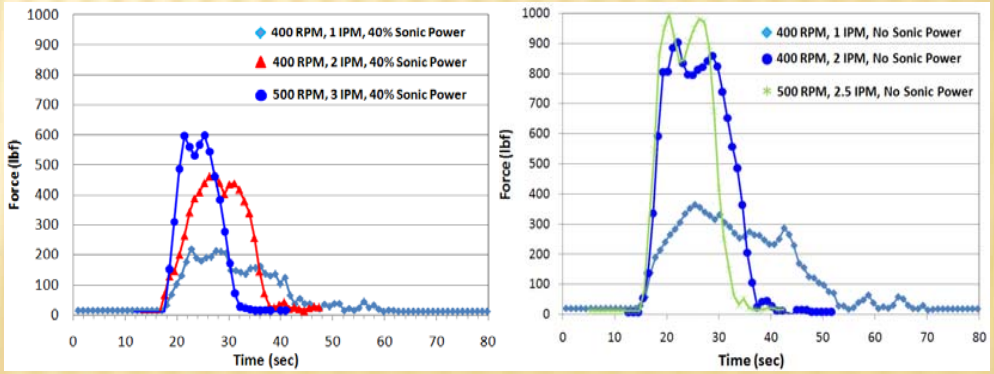
FRICTION REDUCTION

2008 First Experimentation at MSFC

Leased EWI twist drill system

PLUNGE FORCE REDUCTION





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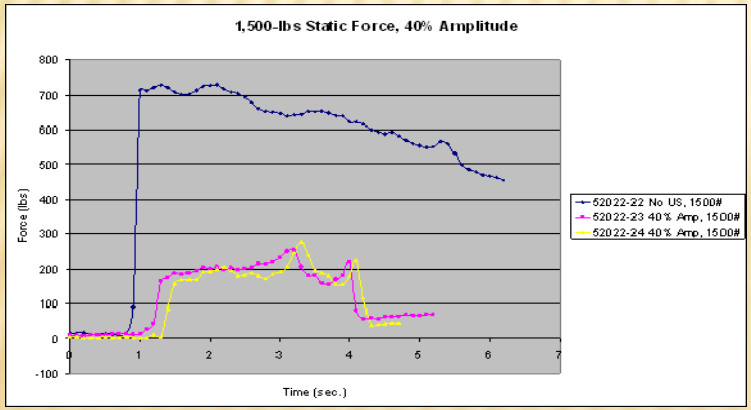
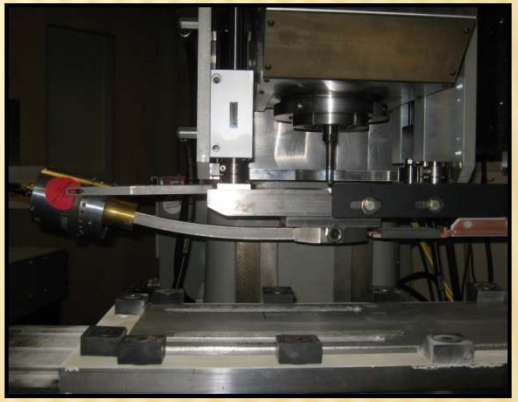
USW PROCESS CHRONOLOGY

2009 - Ultrasonic Friction Reduction Test Bed



2010 - High Temperature Tests of Ultrasonic Friction Reduction



- Bridgeport converted into USW Prototype System in 2012

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Ultrasonic Stir Weld
SHARP

USW SYSTEM CAPABILITIES

- Ability to “pulse” ultrasonic (US) energy on and off and adjust parameters real-time (travel speed, spindle RPM, US amplitude, X and Z axis position, plunge and pin axis force)
- Means to measure draw force.
- Ability to record US power versus time
- Head deflection reduction - two laser height sensors.
- Adding linear encoder to better control tool penetration setting.
- Ultrasonic energy integrated into stir rod and containment plate.
- Maximum 600 RPM.
- Maximum Z force 15,000 pounds.
- Independent control of heating capability via induction technology.

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USW PROCESS ATTRIBUTES

- Decreased plunge forces in Z axis
- Decreased frictional forces in X axis
- Decreased shear forces in X axis
- Increased travel rate
- Increased tool life

FIRST WELDS

- Conducted only three weeks ago
- No induction coil pre-heat
- No pulsing of US power
- Aluminum 2219 .250-in

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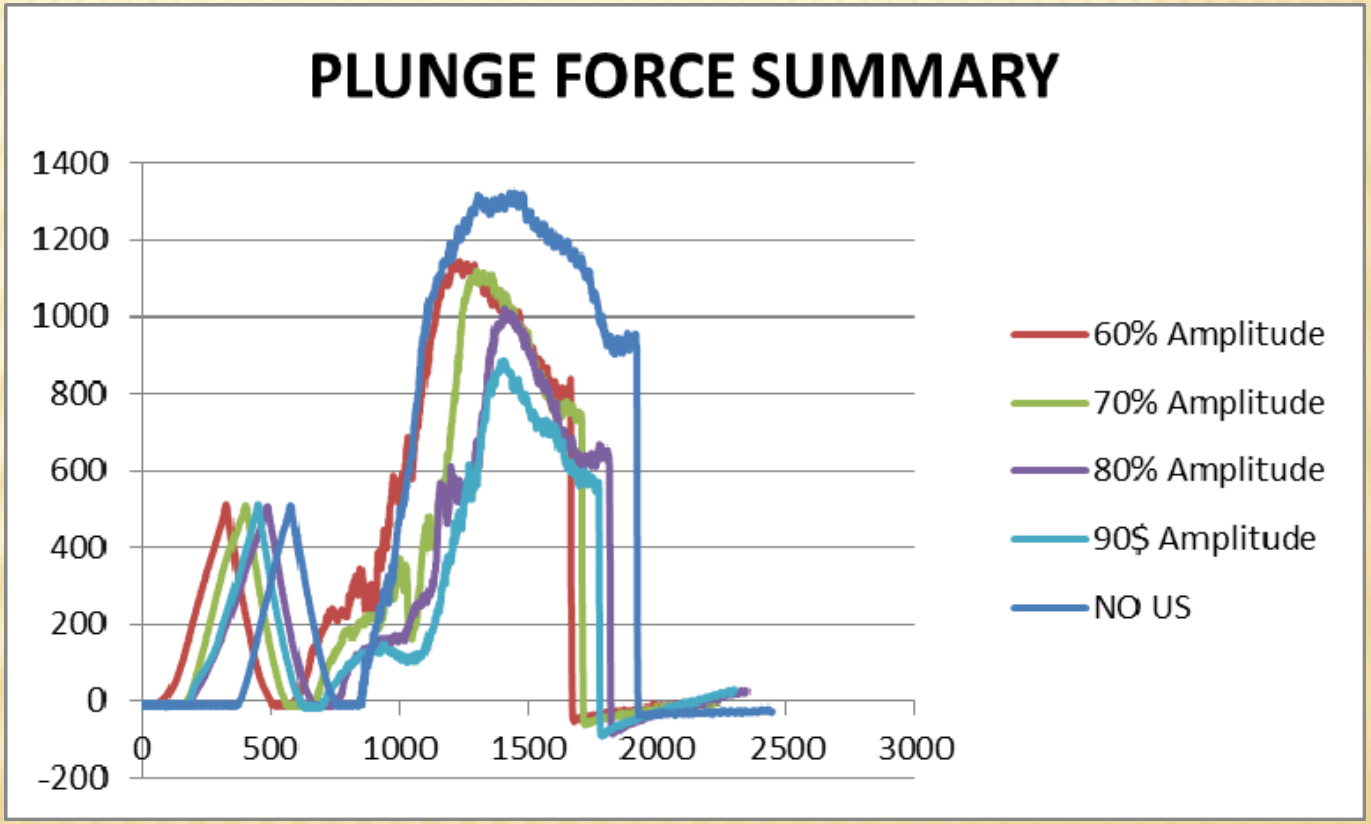
PLUNGE FORCE CHARACTERIZATION

Procedure: Plunged stir rod travelling .25 IPM varying ultrasonic amplitude
High: 1324 lb. Low: 886 lb. Delta: 33% reduction



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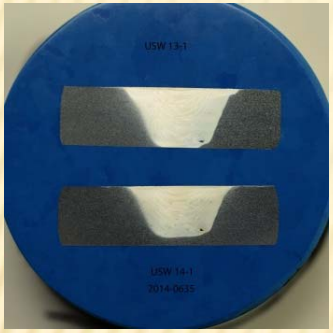
TEST PANEL 14

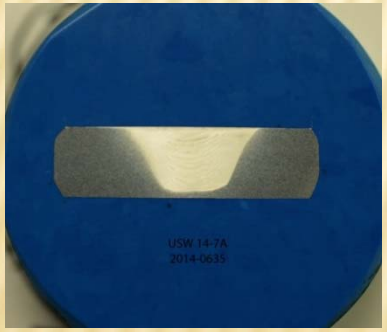
Procedure: Plunged stir rod travelling .25 IPM
Travel=4 IPM

No CP/Spindle US
350 RPM



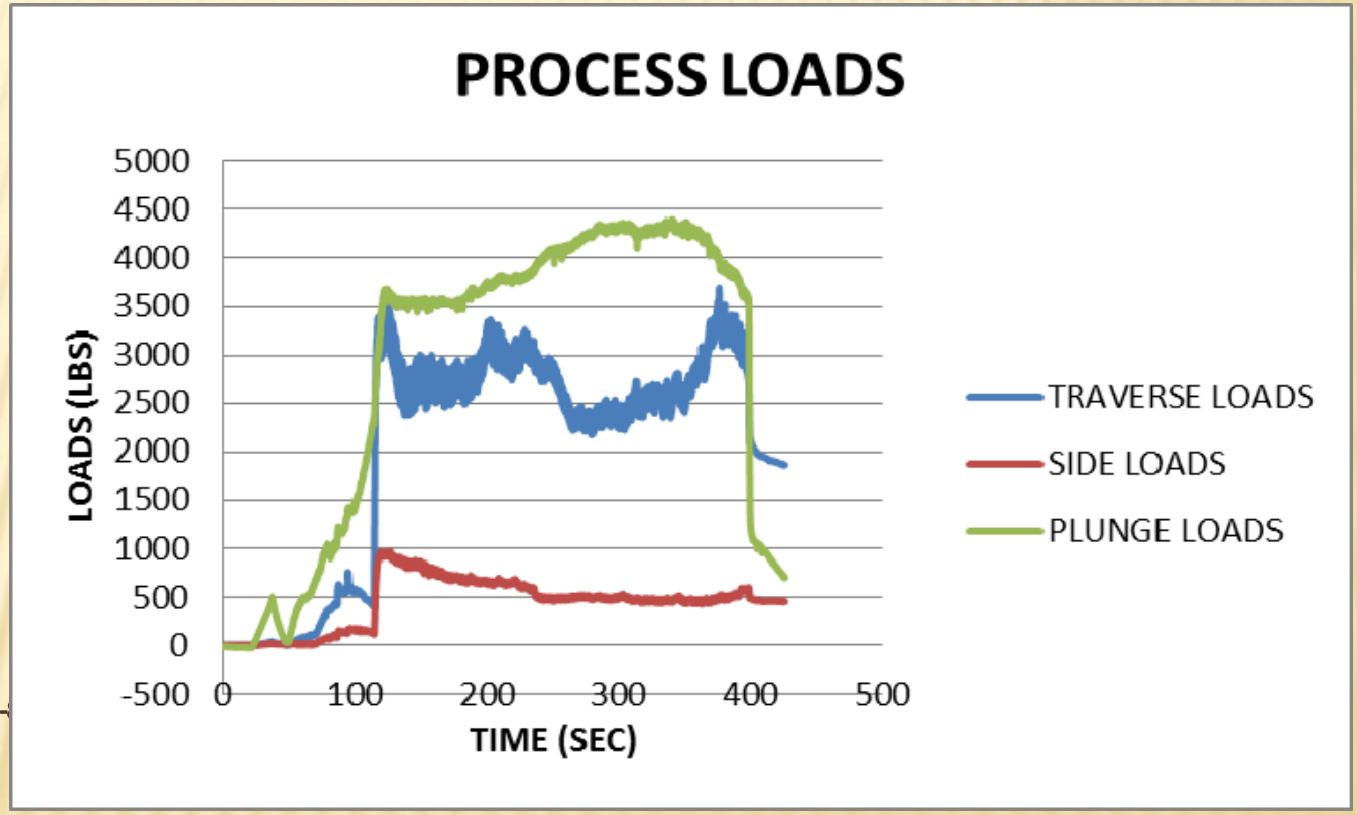
13-1
14-1

T_{ult} = 29.07 ksi
T_{yld} = 29.04ksi



14-

T_{ult} = 40.81 ksi
T_{yld} = 29.42ksi



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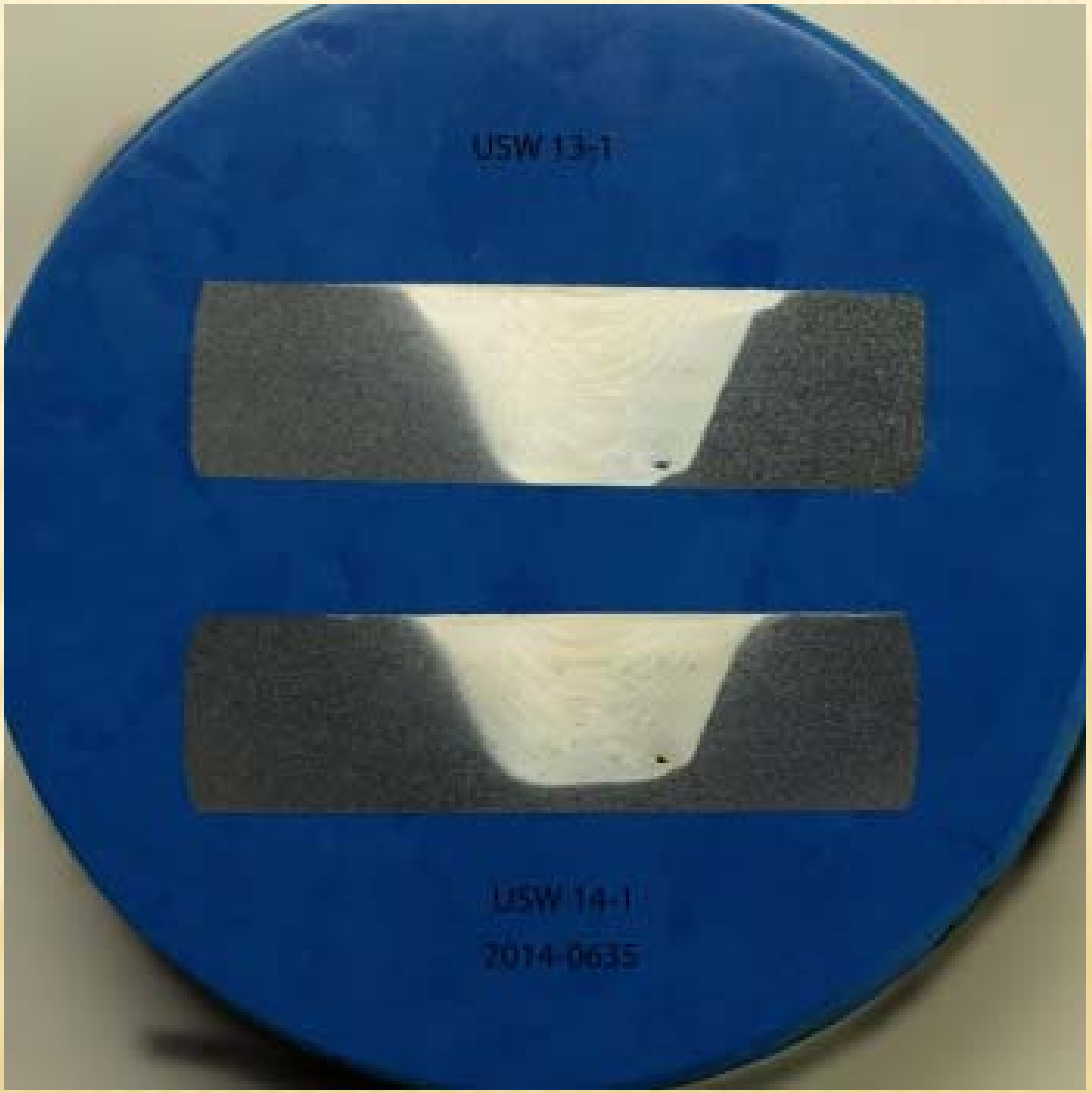
COMPARISON OF 13-1 TO 14-1



13-1
90% Amplitude

14-1
0% Amplitude

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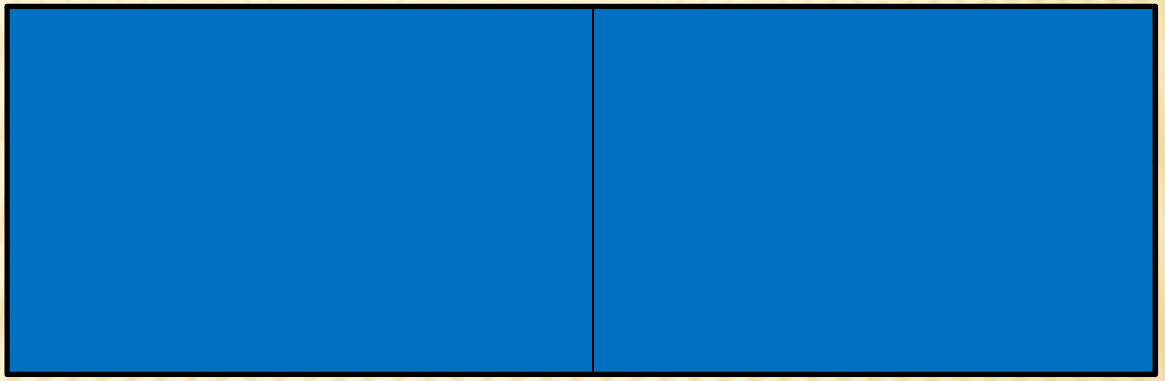
TEST PANEL 12

EFFECT OF SPINDLE ULTRASONICS ON WELD NUGGET AT DIFFERENT AMPLITUTUDES
Containment Plate Ultrasonics 50% Amplitude
Travel = 4 ipm RPM = 350 RPM



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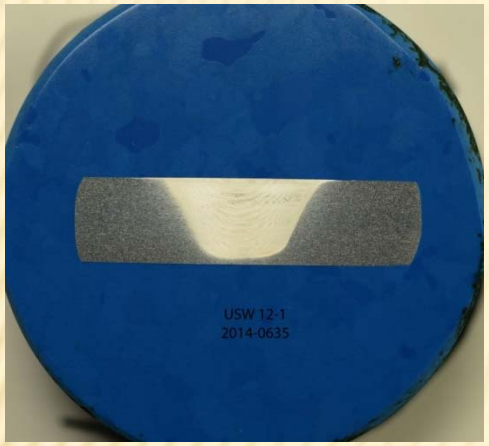
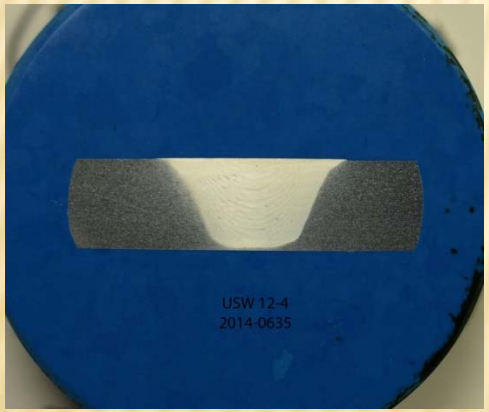
TEST PANEL 12



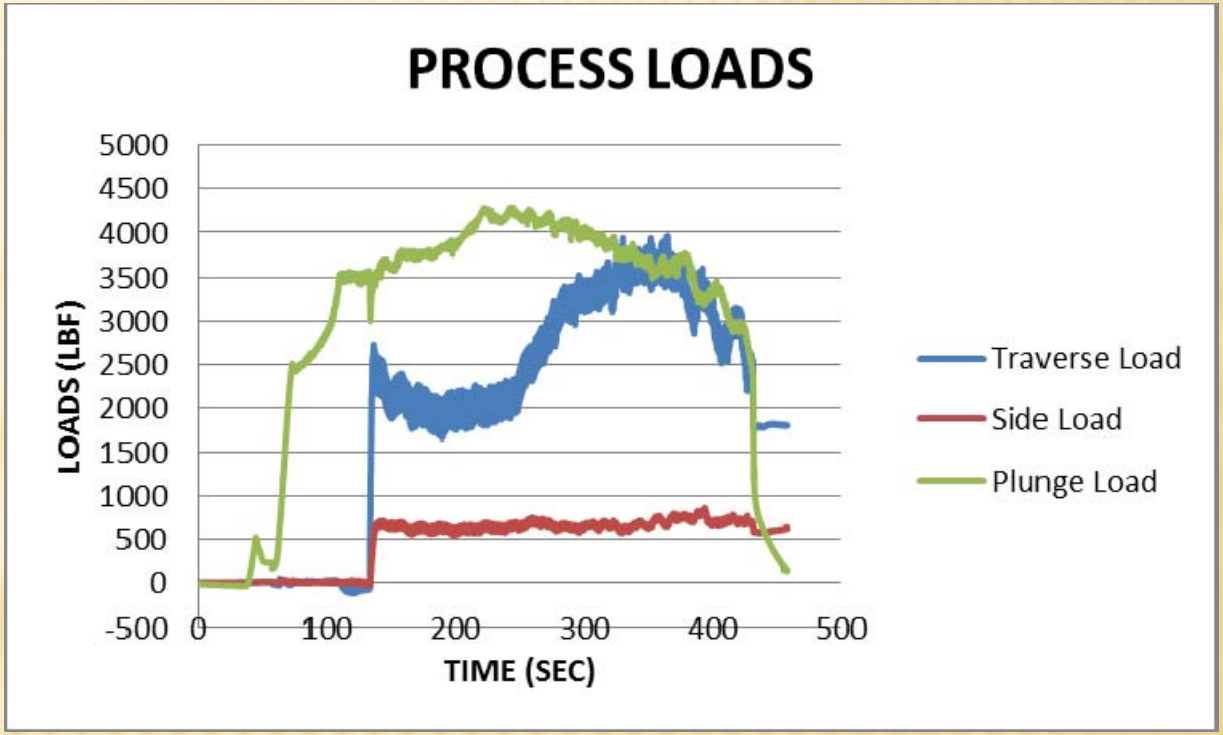
12-1
SPU=90%
CPU=50%

T_{ult} = 41.82 ksi
T_{yld} = 28.67ksi



12-4
SPU=0
CPU=50%

T_{ult} = 44.75 ksi
T_{yld} = 30.82ksi



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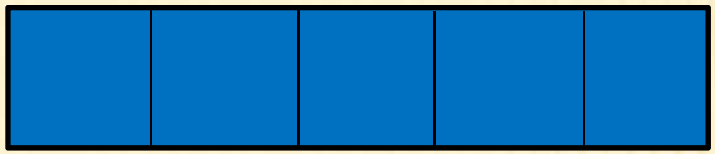
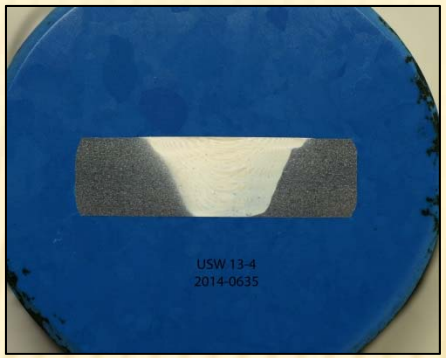
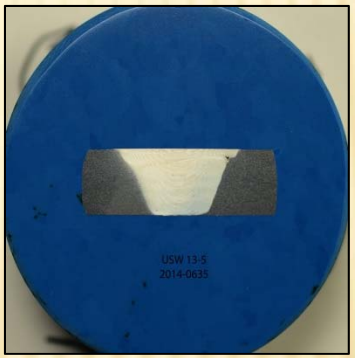
TEST PANEL 13



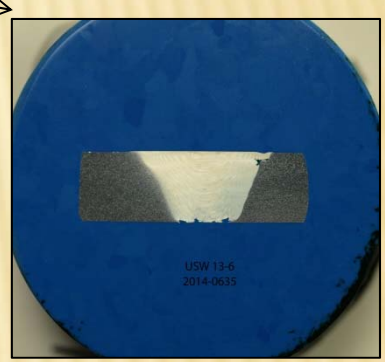
T_{ult} = 46.65 ksi
T_{yld} = 31.16 ksi



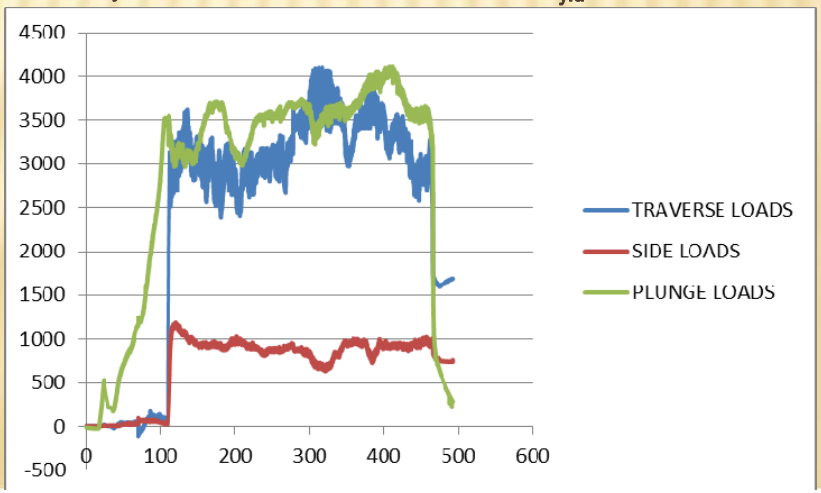
T_{ult} = 42.40ksi
T_{yld} = 3 2.49 ksi



T_{ult} = 45.88 ksi
T_{yld} = 33.54 ksi



T_{ult} = 33.91 ksi
T_{yld} = 31.12 ksi



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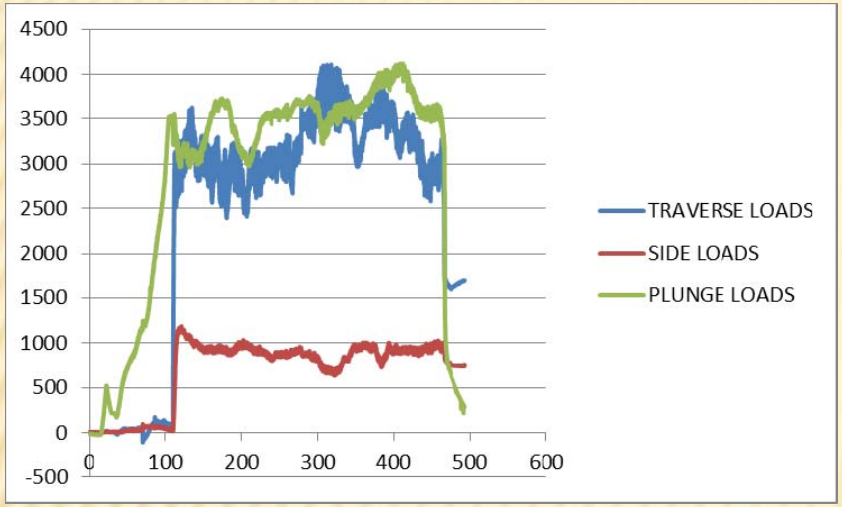
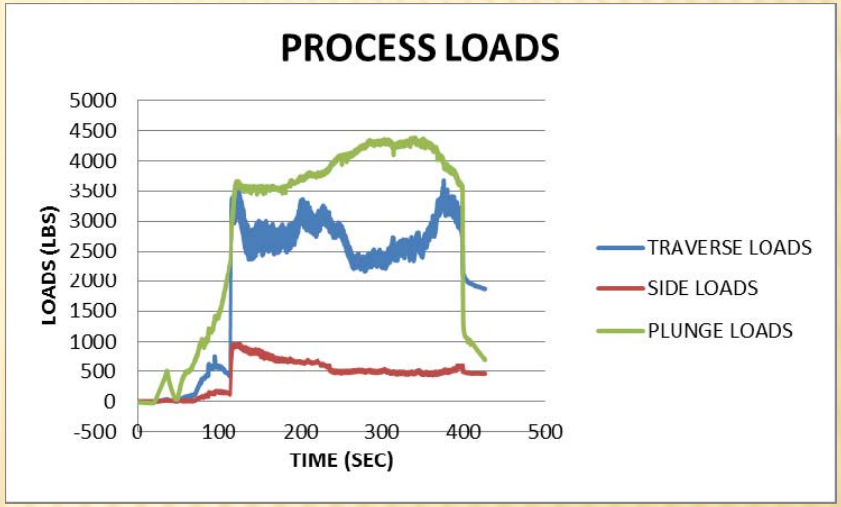
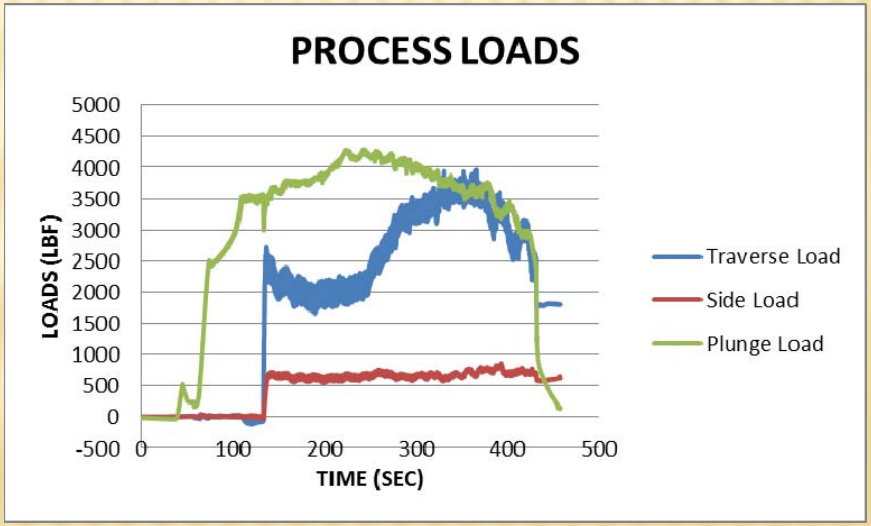
TEST PANELS 12- 14



Panel 13



Panel 14



Panel 12

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FUTURE WORK

- Address penetration issue
- Begin induction coil pre-heat
- Characteristics of hot weld versus cold weld
- Pulse ultrasonics on/off
- Determine upper limit of CP amplitude
- Faster travel rates
- Develop parameters for heat resistant alloys

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TECHNOLOGY LICENSING OPPORTUNITIES

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September 17, 2014

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