Determining Bond Quality of UAM

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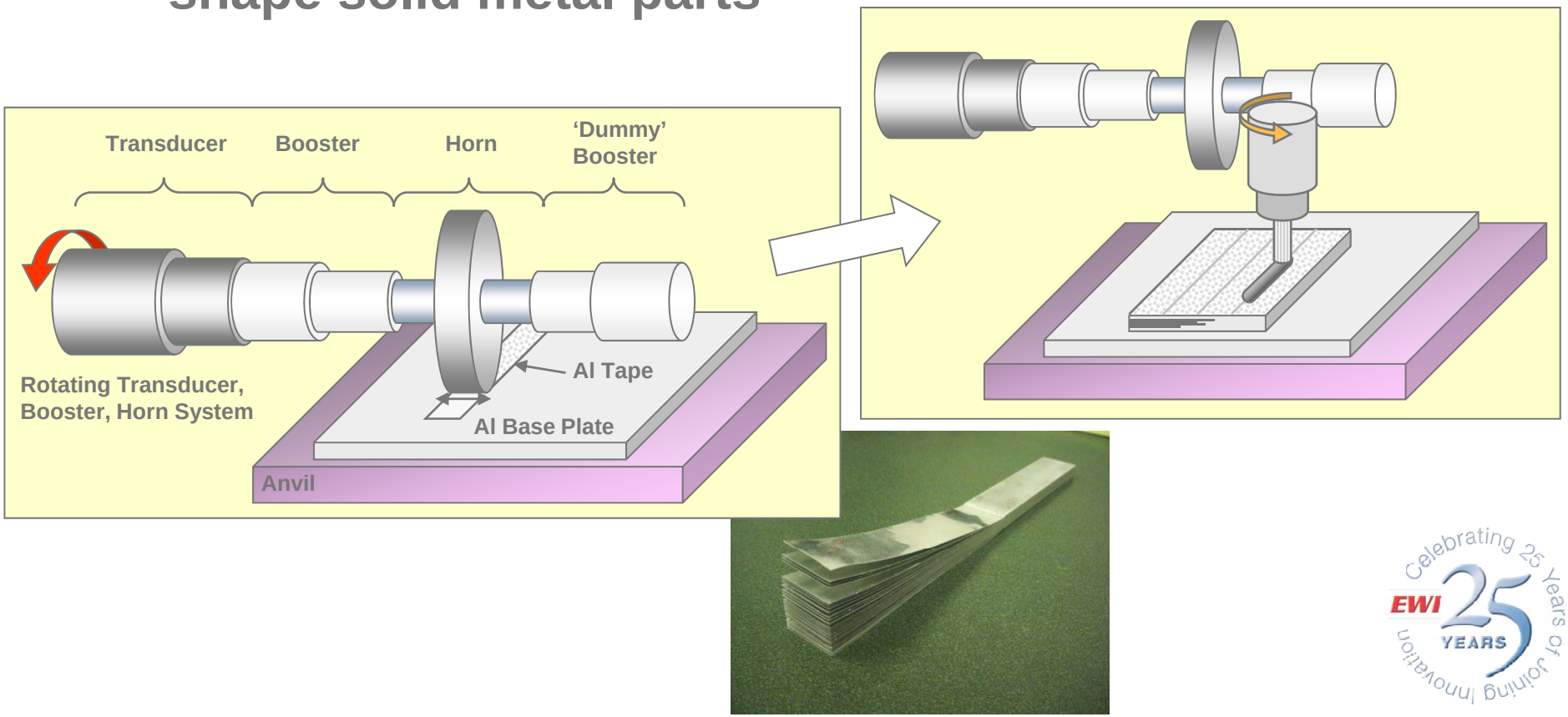
Outline

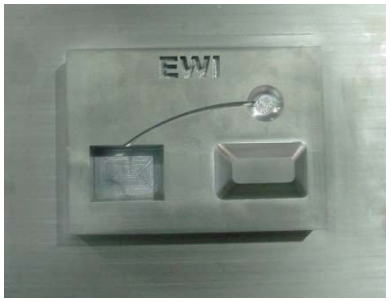
- Background of UAM process
- Challenges
- Developments
- Attempts to model the process
- Determining bond quality based on feedback controls
- Summary

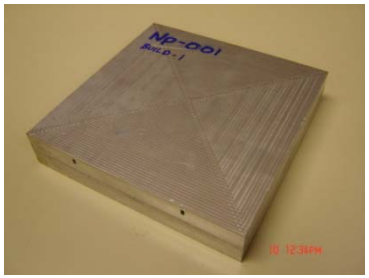
Ultrasonic Additive Manufacturing

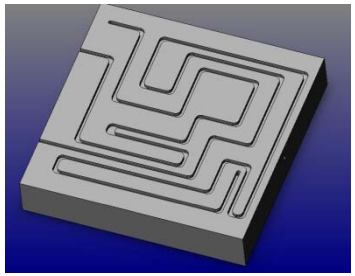
- … a new technology – “UAM” uses solid state ultrasonic metal welding (UMW) to create net-shape solid metal parts

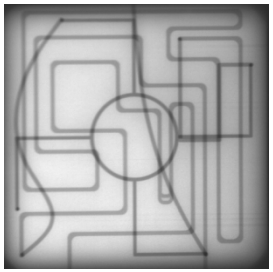


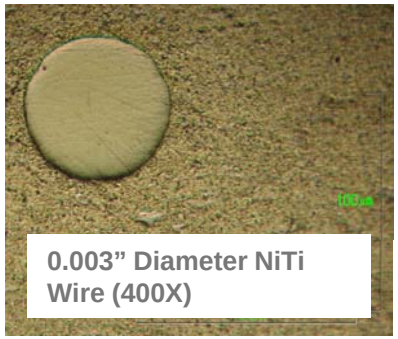
Applications

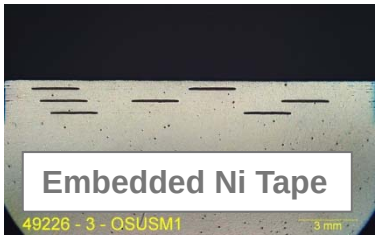












- Range of emerging applications … rapid prototyping, low volume tooling, direct parts manufacture, tailored materials, MMC, embedded fibers, smart materials, sensors, cladding, armor, thermal management

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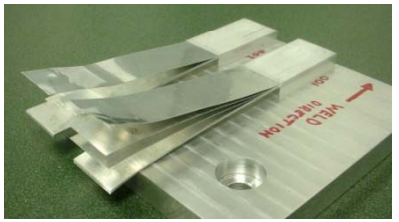
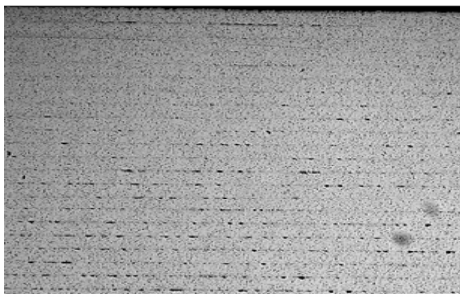
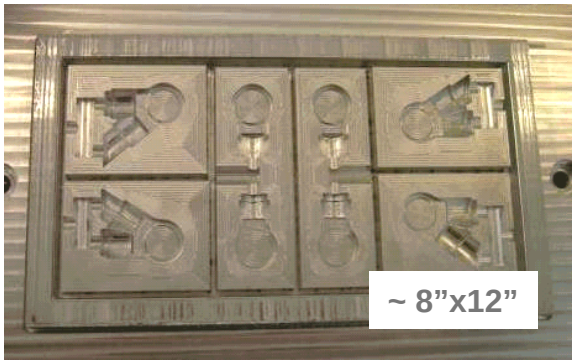
EWI 25 YEARS

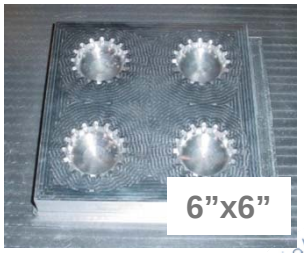
Challenges for UAM to Meet Industry Needs

- Materials – limited to 3XXX Al alloys (Al-Ti, Cu). Not SS, Ti, 7XXX Al, HSS, Ni-based
- Tape thickness – thin tapes (0.006”/0.15mm T typical)
- Tape width – narrow width (1.0”/25mm typical)
- Joint strength
- Production speed – order of few 10s ipm
- Part size – relates to restricted speeds, tapes, material ~ 300 in^3 work envelope









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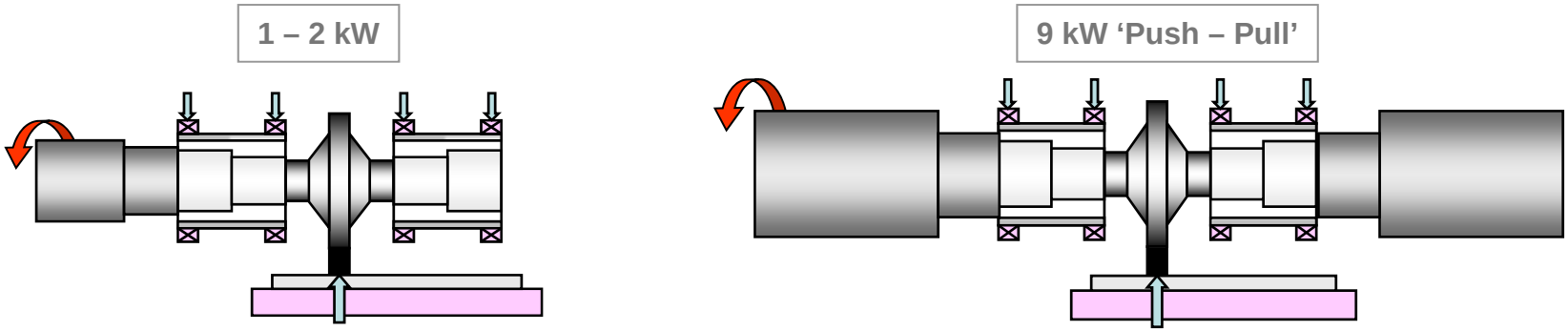
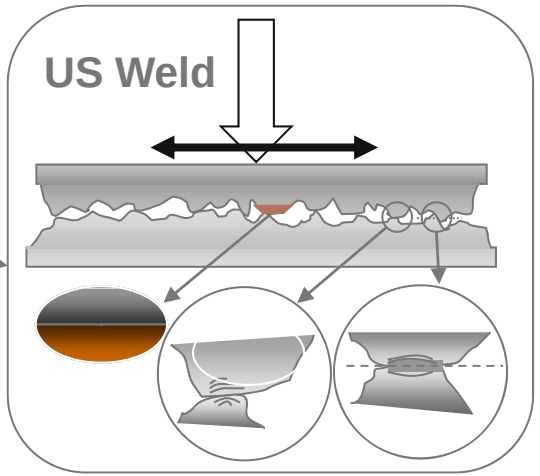
The Approach …

- Major increase of US power – from 1 – 2 kW to 9 kW (later increases to 12 – 15 kW are possible)



- Increased US power impacts materials, tape dimensions, bond strength, welding speed, part size



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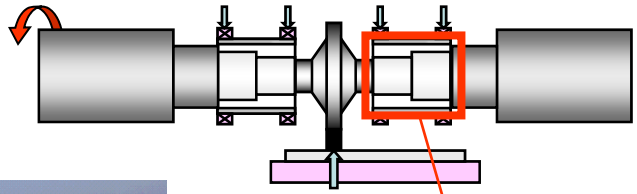
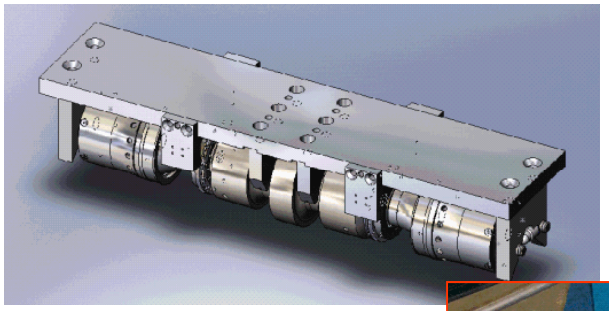
Supporting Developments

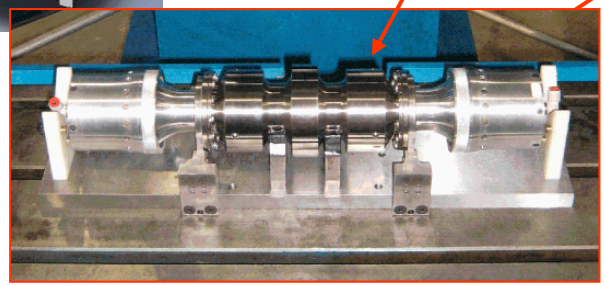
EWI Solidica System

9 kW Push-Pull

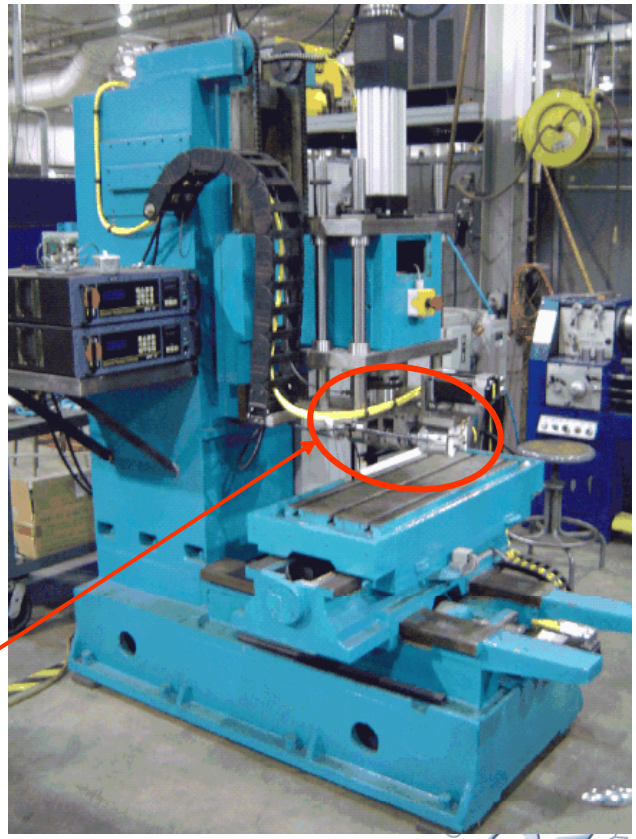




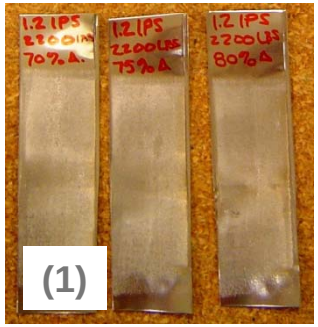
Booster eliminated

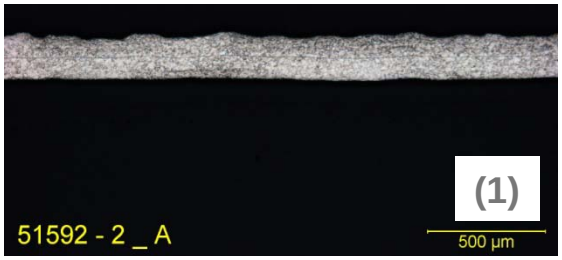


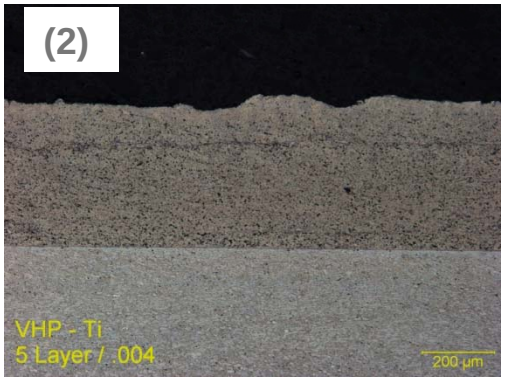
VHP Test Bed

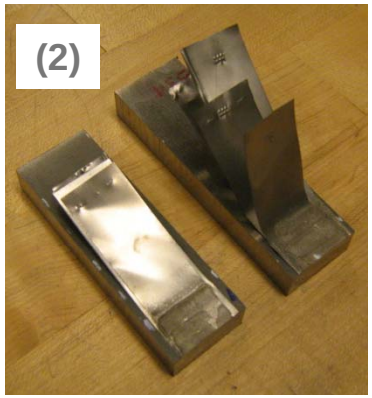


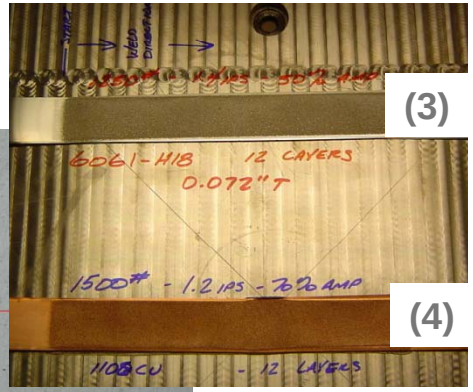
Results with Advanced Materials

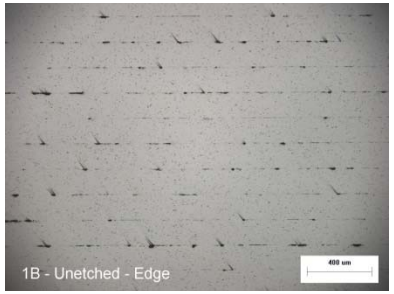


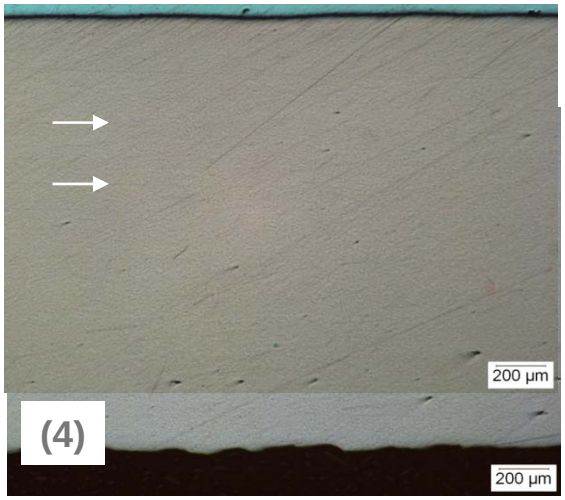


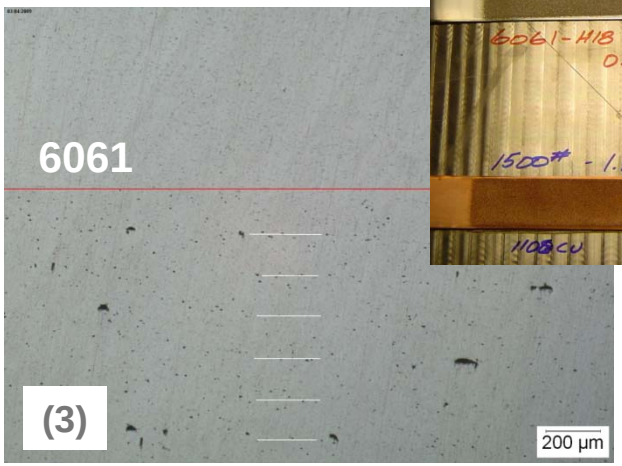












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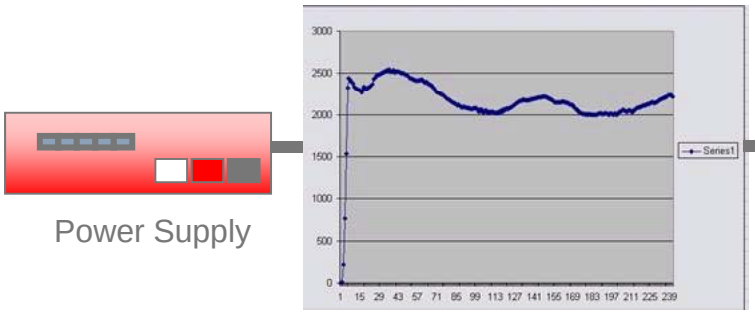
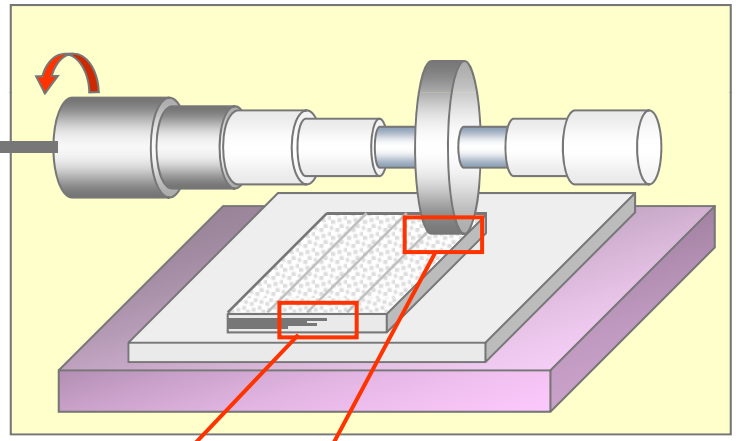
Issue, Challenge, Question …

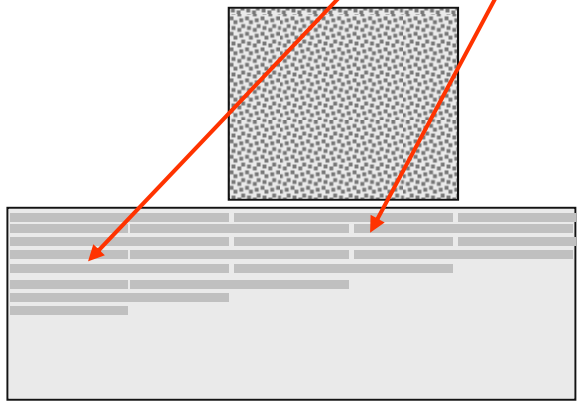
- Can we infer, deduce, measure quality of the weld from power supply power and/or impedance data?



Power Supply

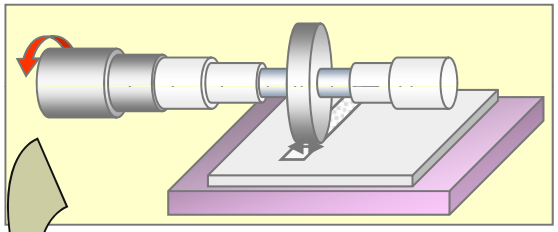
Weld Power vs Position

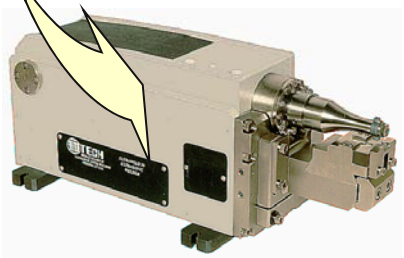


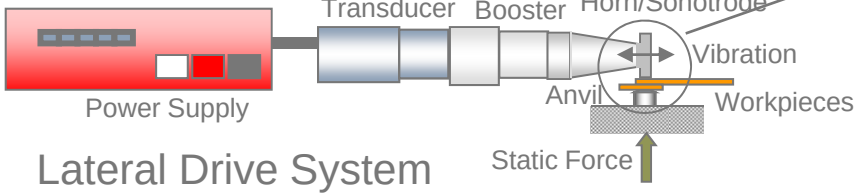


Concepts from UMW …

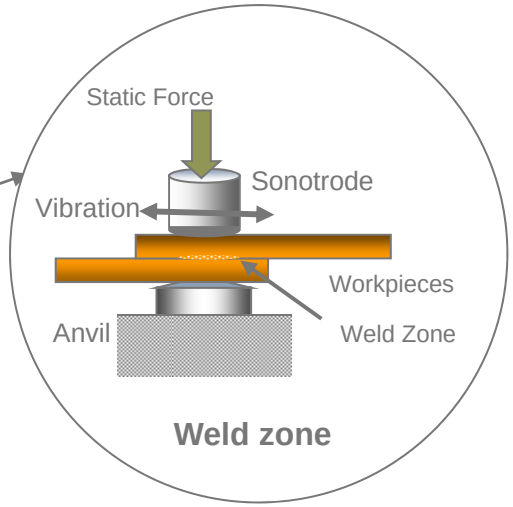
- Know that … UAM is based on US metal welding (UMW)



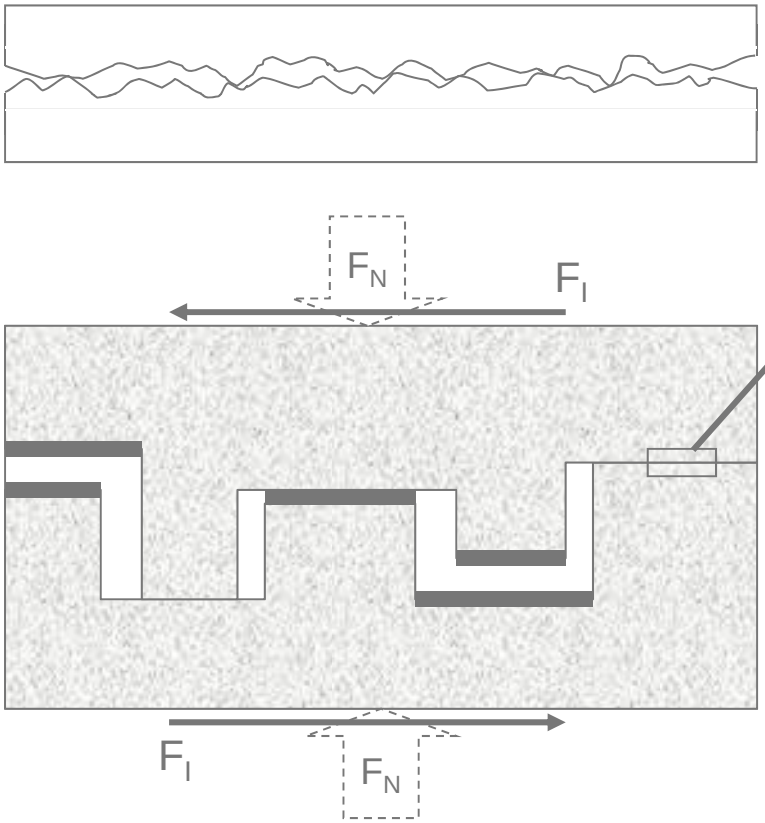


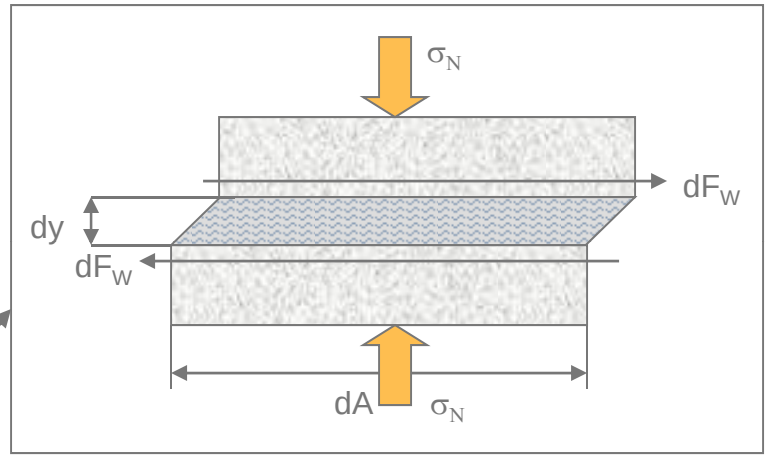


Lateral Drive System



Modeling Shear Forces





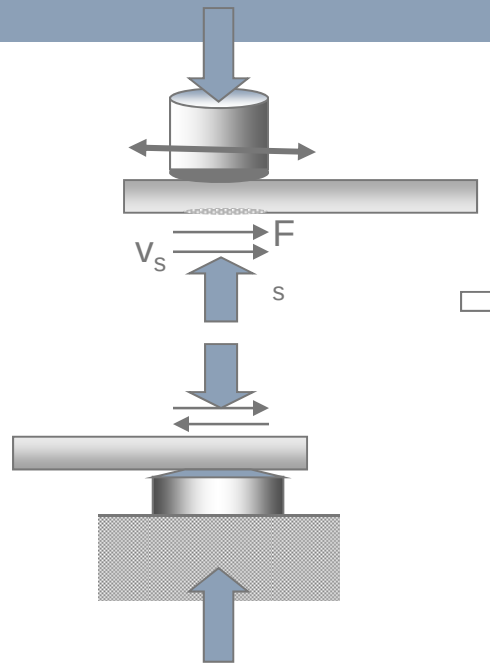
Integration over the time-dependent weld area gives the temperature, normal force and time-dependent welding force:

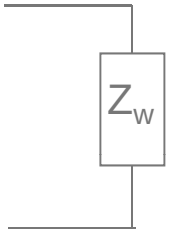
$$F_W(T, F_N, t) = \sqrt{\left(\frac{Y(T)}{2}\right)^2 - \left(\frac{F_N / A_{DZ}}{2}\right)^2} * A_W(t)$$

$$A_W(t) = A_0(1 - e^{-t/T})$$

Knowing Shear Force …

- Possible control technology – Weld impedance $Z_W = F_s/v_s$.

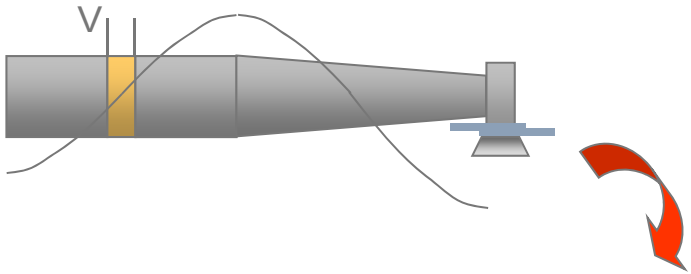


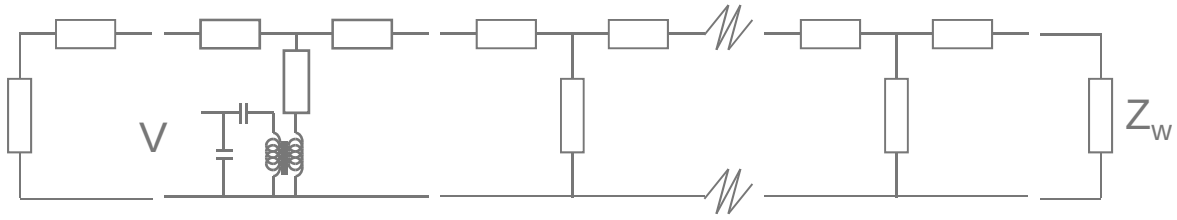


F_s ~ Shear Force
v_s ~ Shear Velocity
$Z_W = F_s/v_s$

~ Weld Impedance

Impedance Representation of the Weld

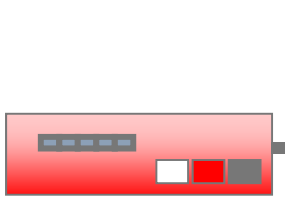




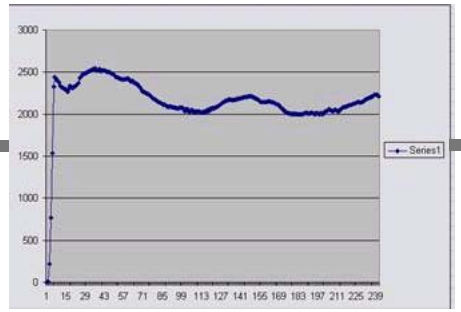
Chain of Transfer Functions

Back to the Question …

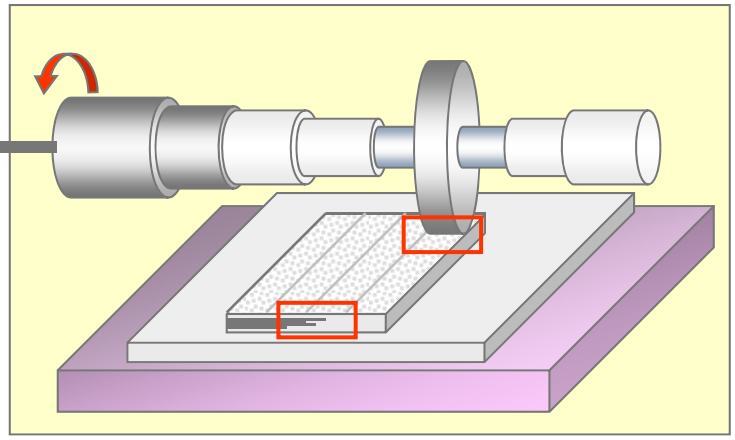
- Based on weld impedance and network concepts, it should be possible to “infer, deduce, measure” some aspects of weld quality from power supply power and/or impedance data?



Power Supply

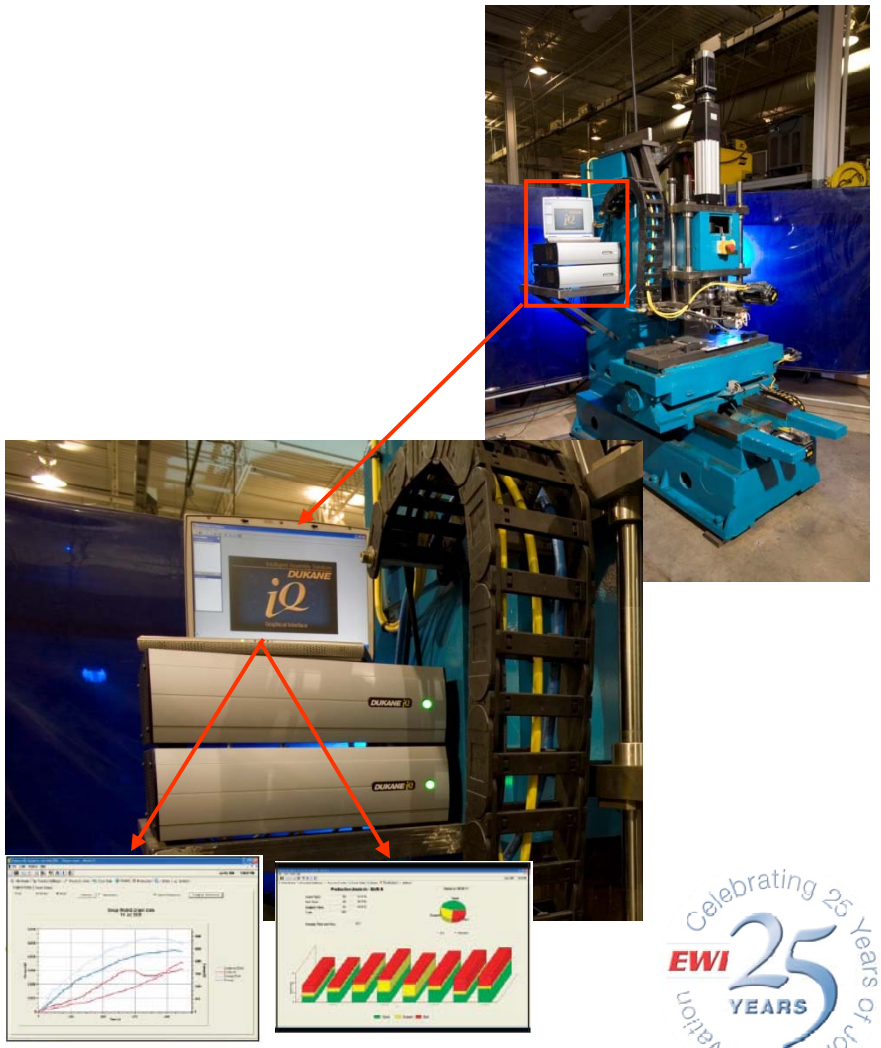


Weld Power vs Position



Determining bond quality

- Making the most of today's control technology for UAM
  - Recently upgraded VHPUAM Testbed with most advanced control technology available from Dukane (iQ Explorer)
    - Power, Frequency, Energy, and Amplitude feedback for entire weld cycle
    - Power distribution and ramp-up control
  - Data acquisition capabilities for production type setups



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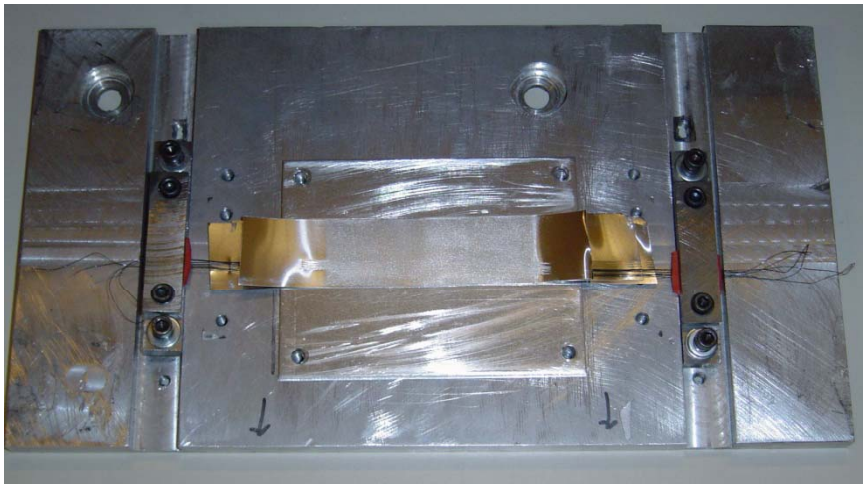
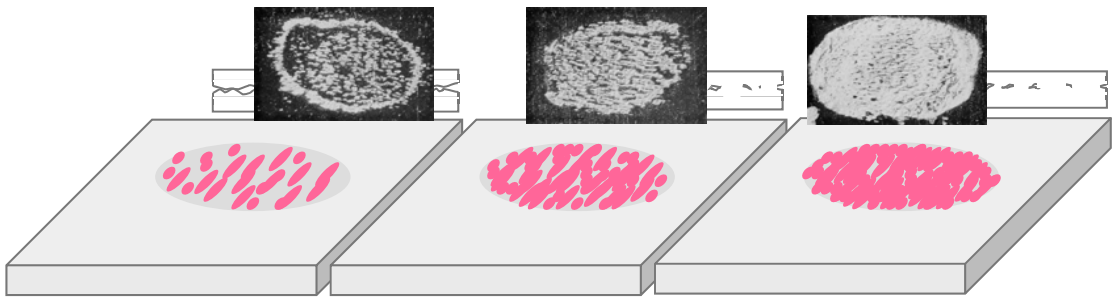
Determining bond quality cont.

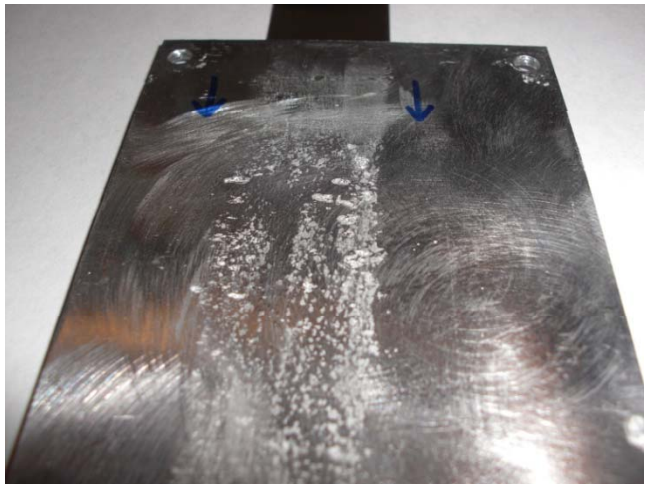
- This is a good weld… but,

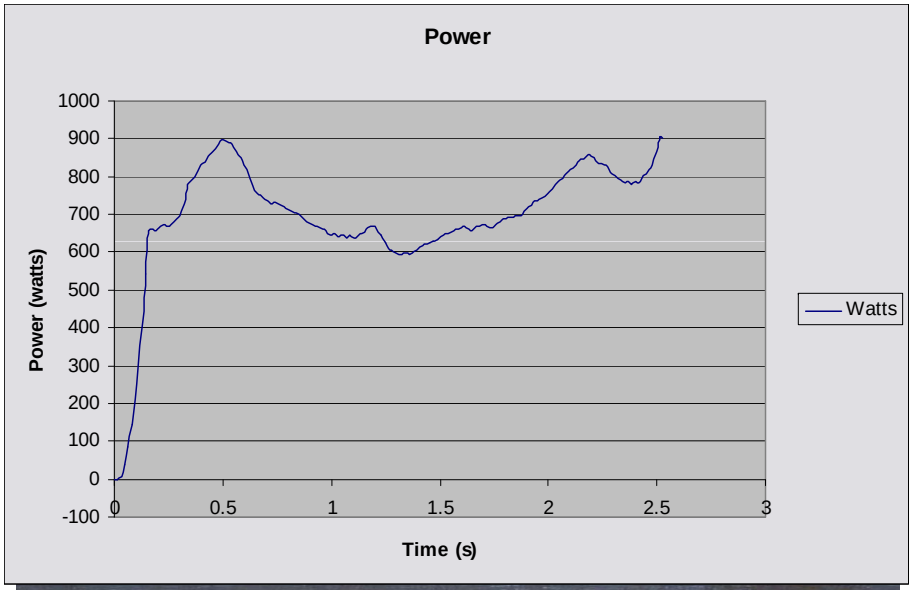




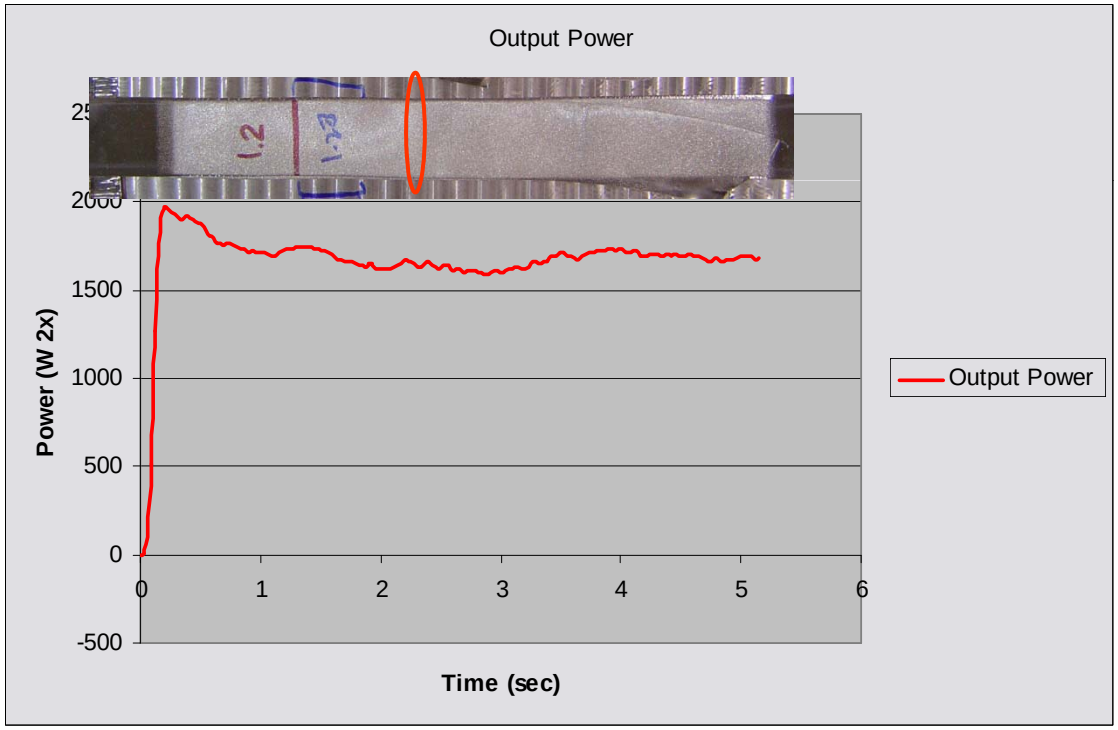
Determining bond quality cont.

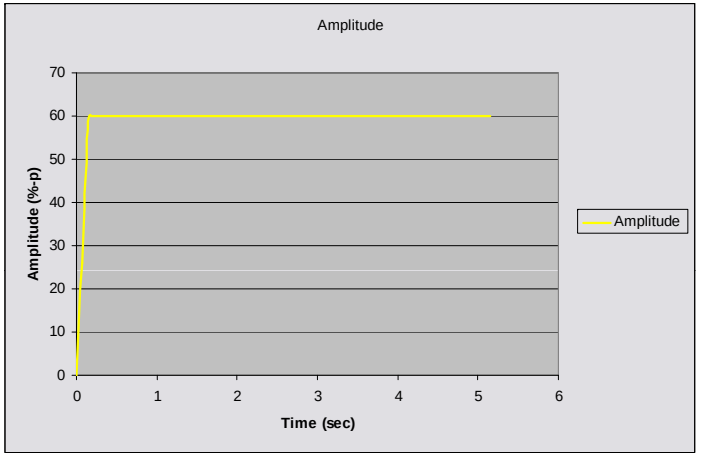
- Evaluating power distribution throughout the weld cycle can tell us a lot
  - Recall the systems mechanical impedance

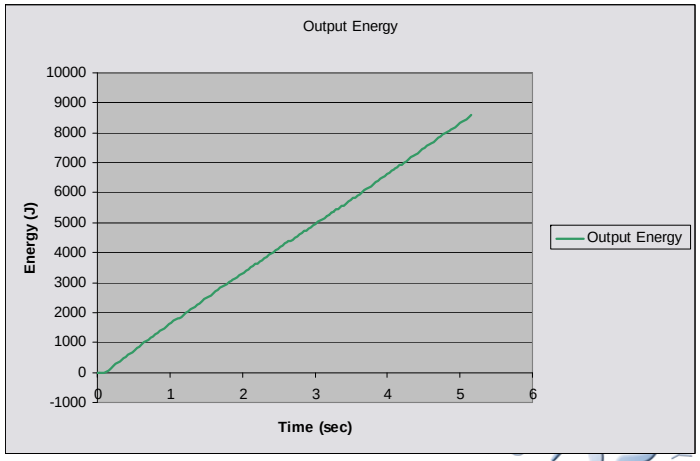




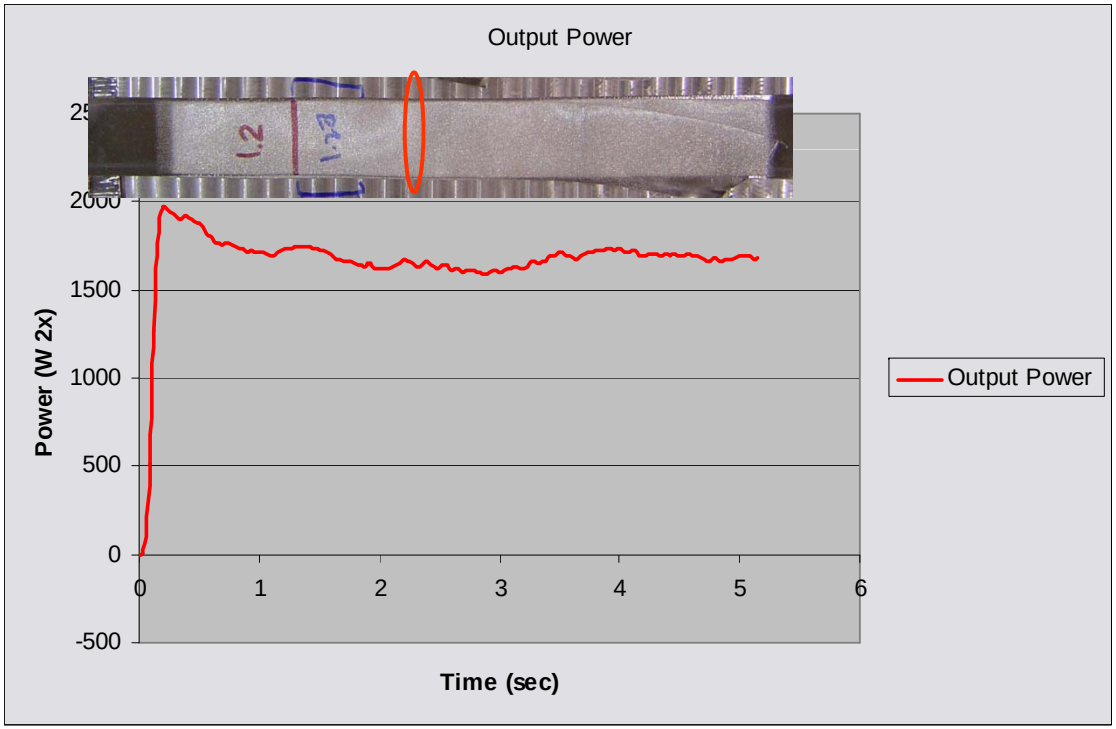
Determining bond quality cont.

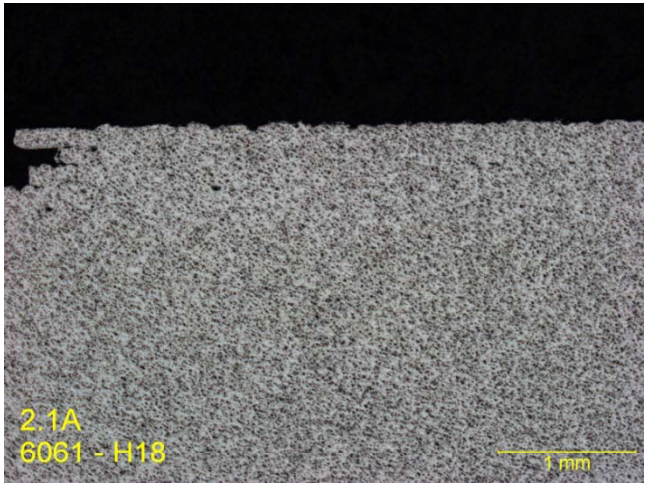


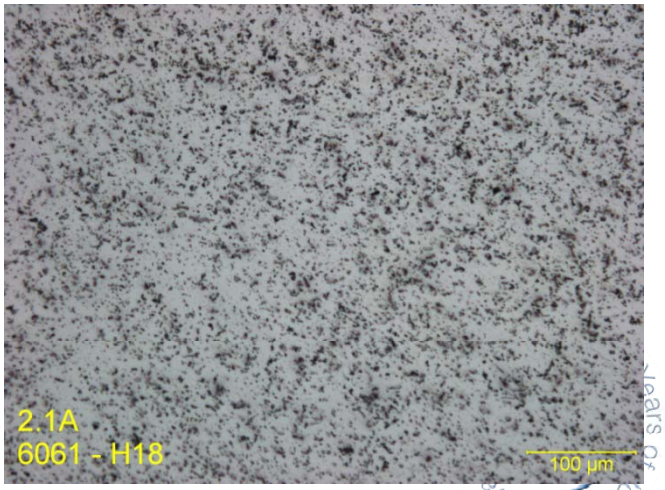




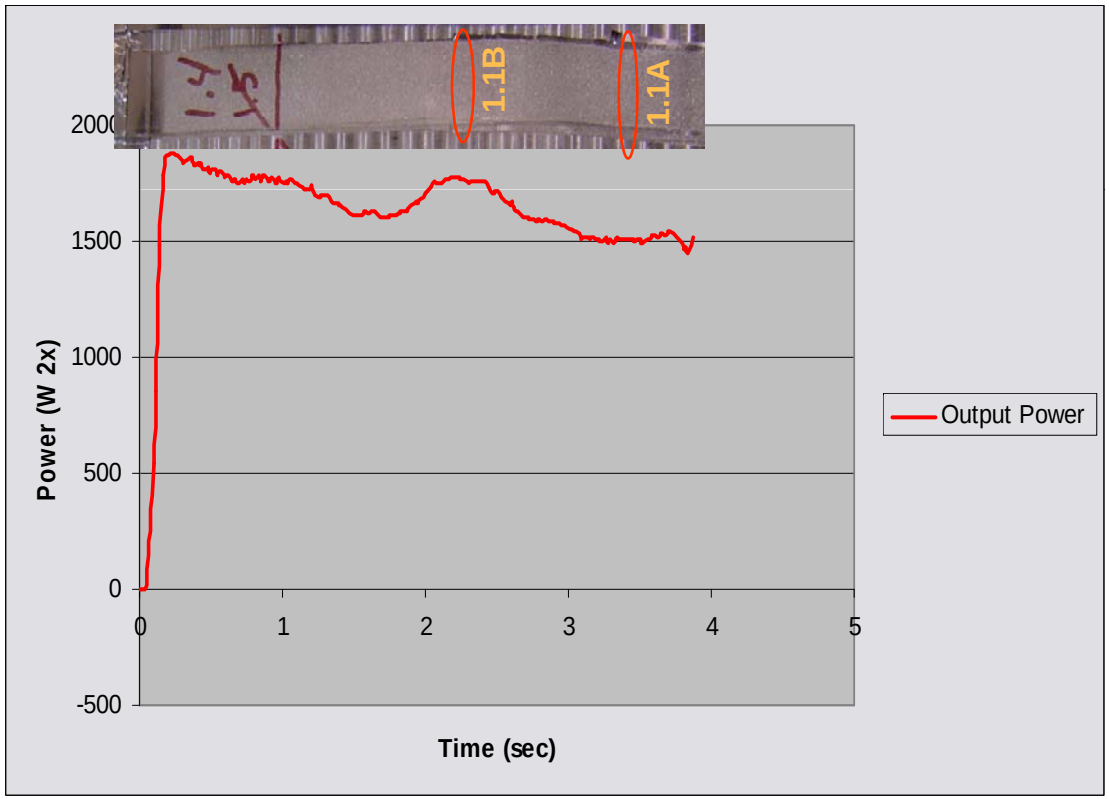
Determining bond quality cont.

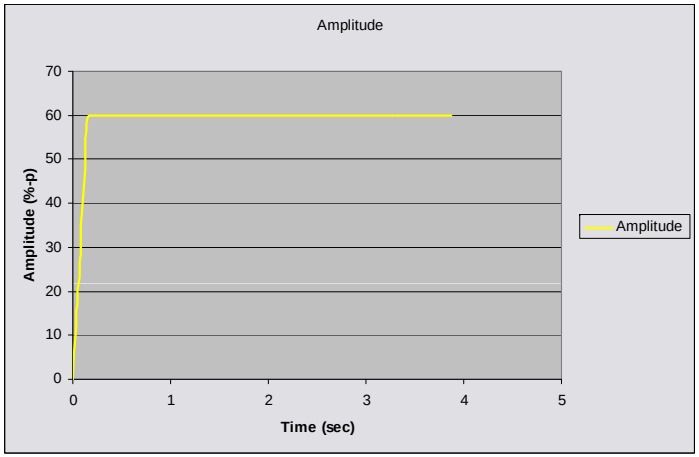


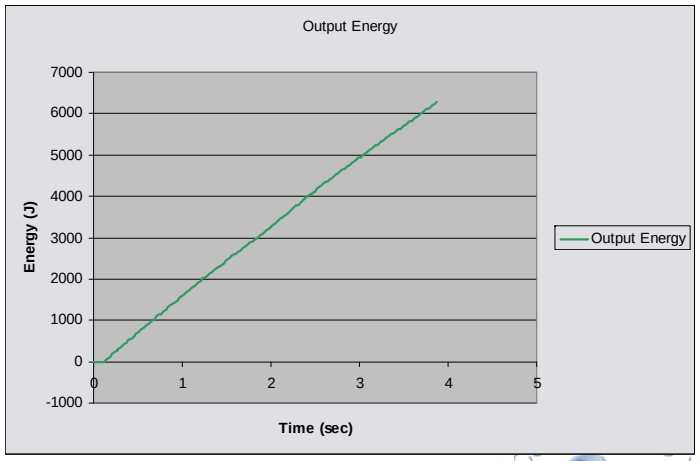




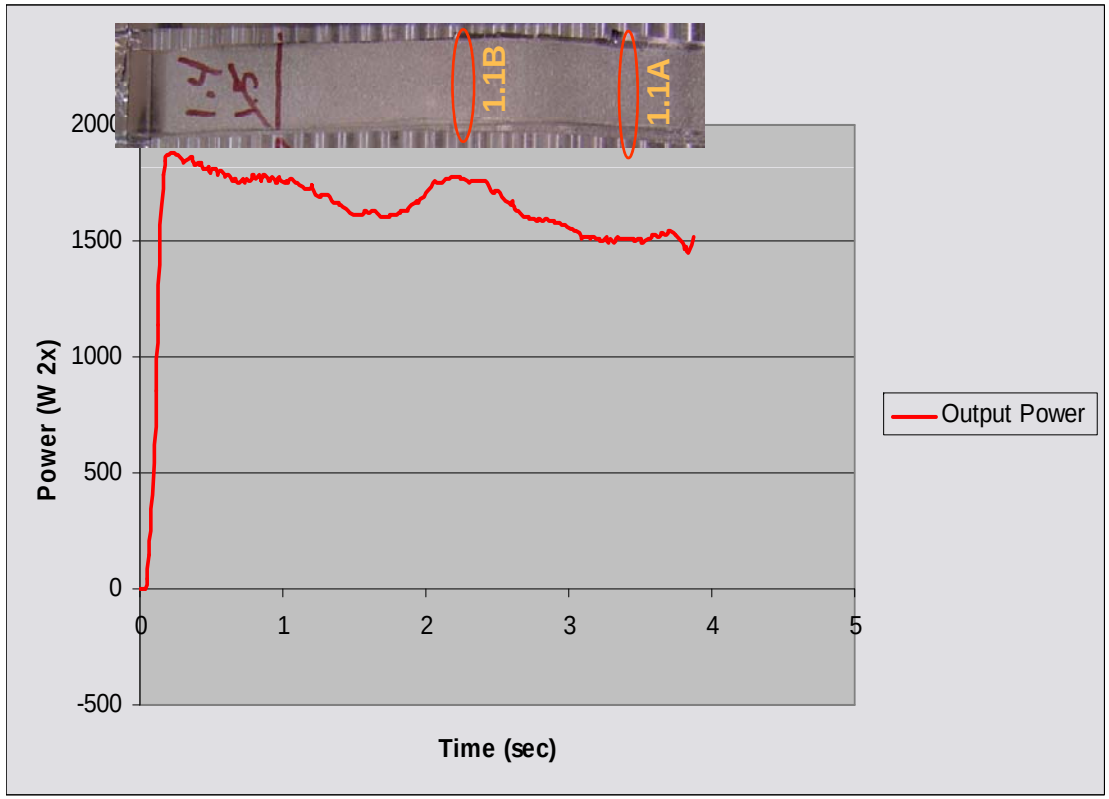
Determining bond quality cont.

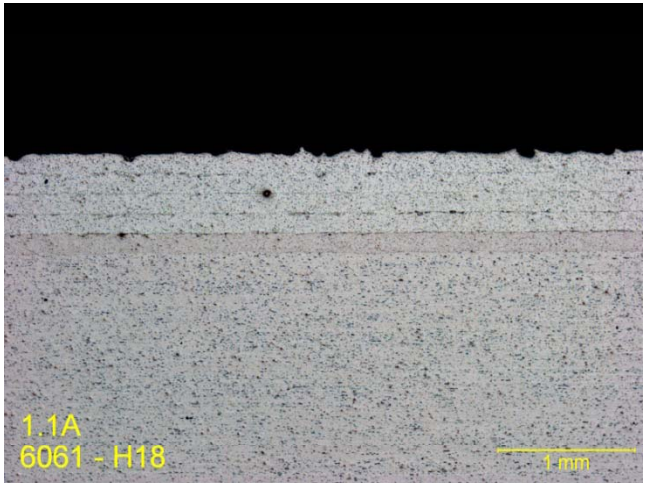


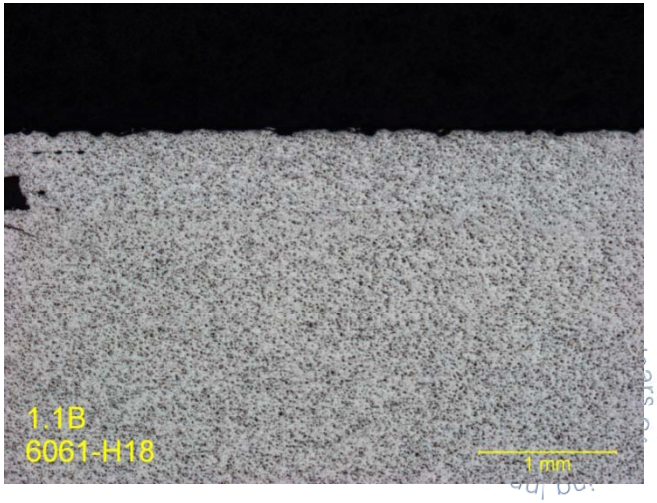




Determining bond quality cont.







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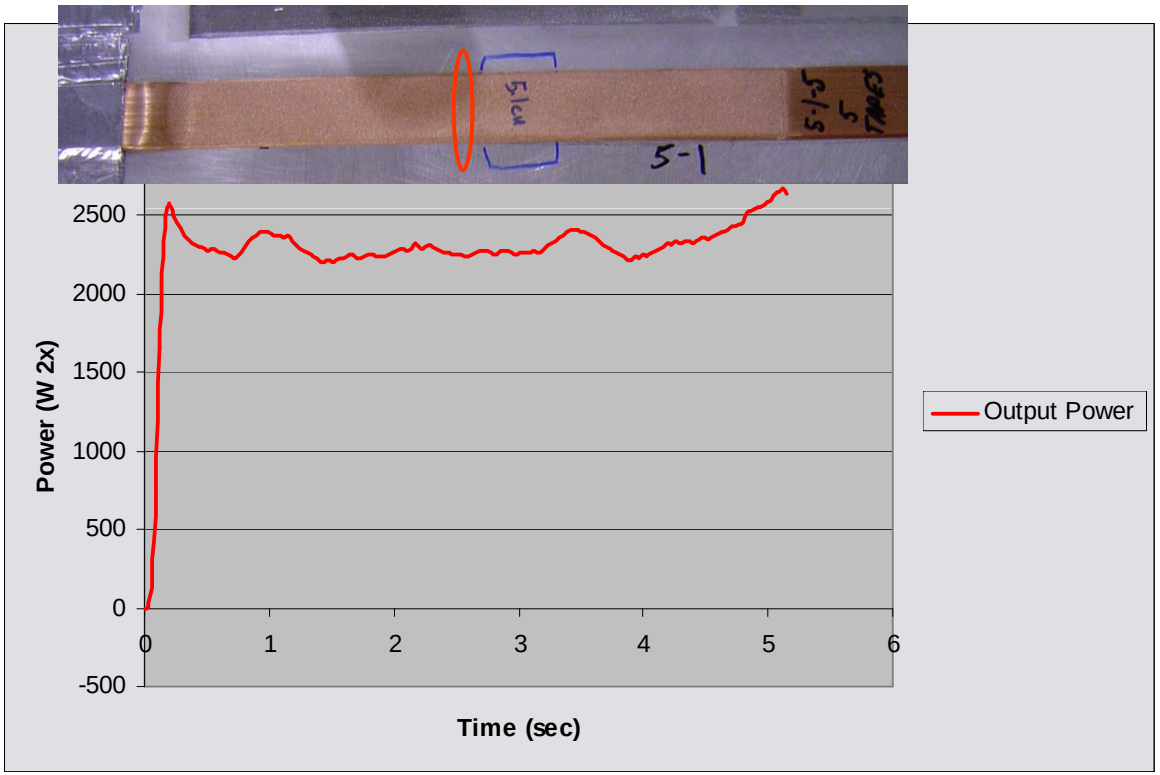
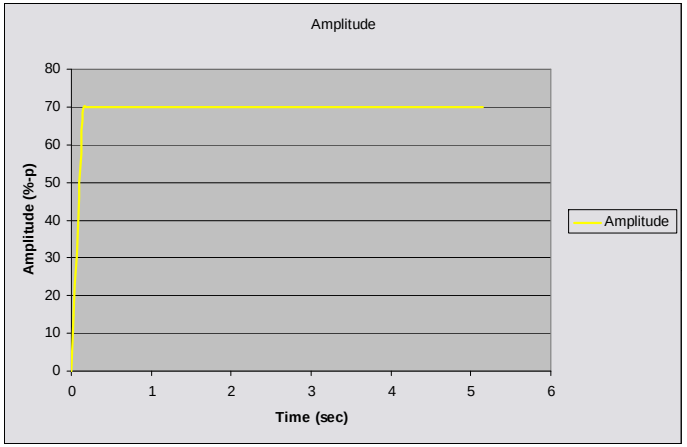
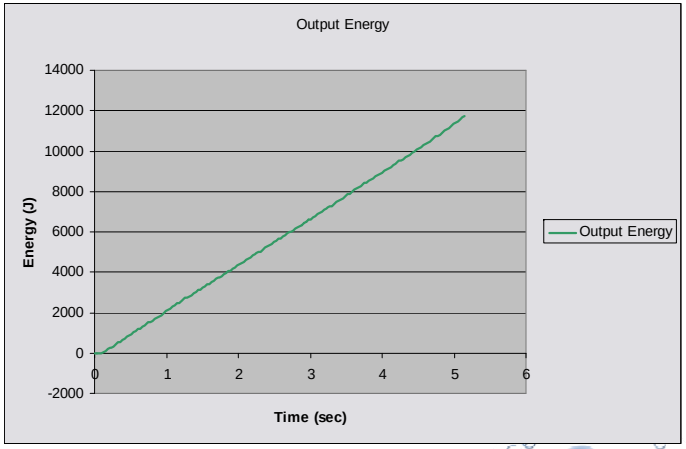
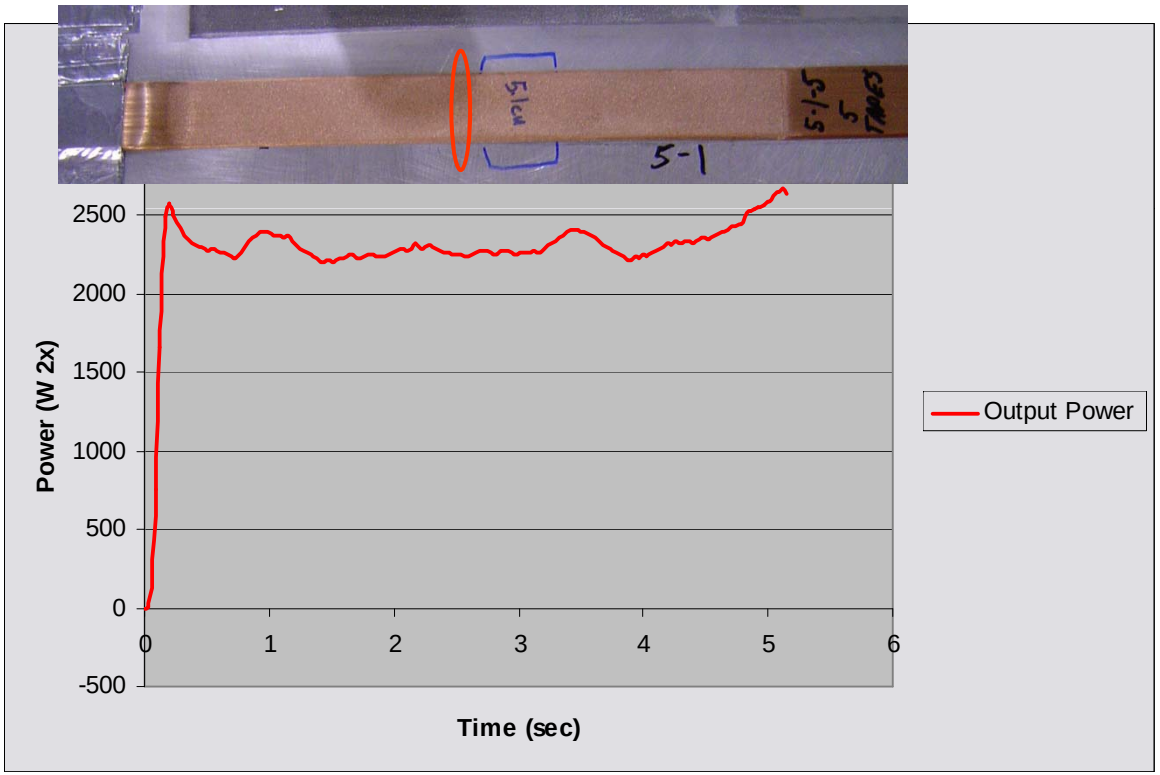
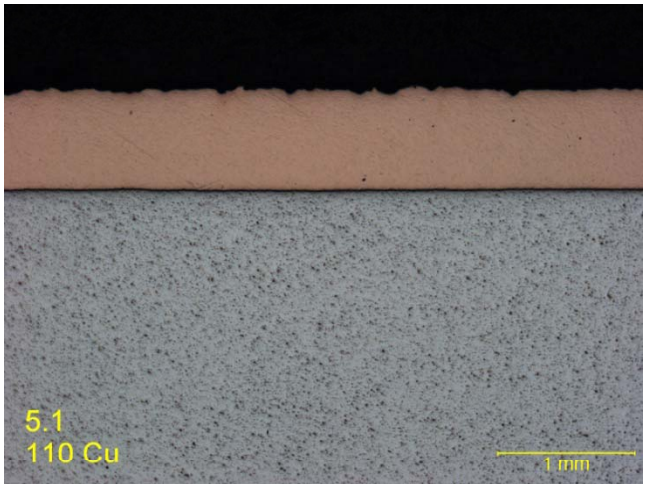


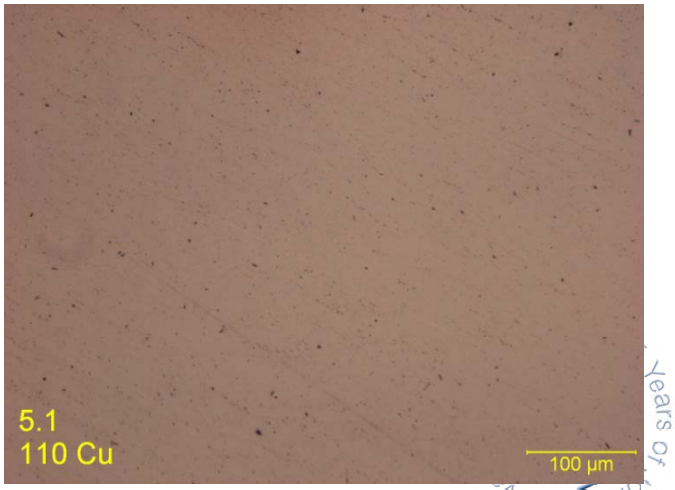




Determining bond quality cont.

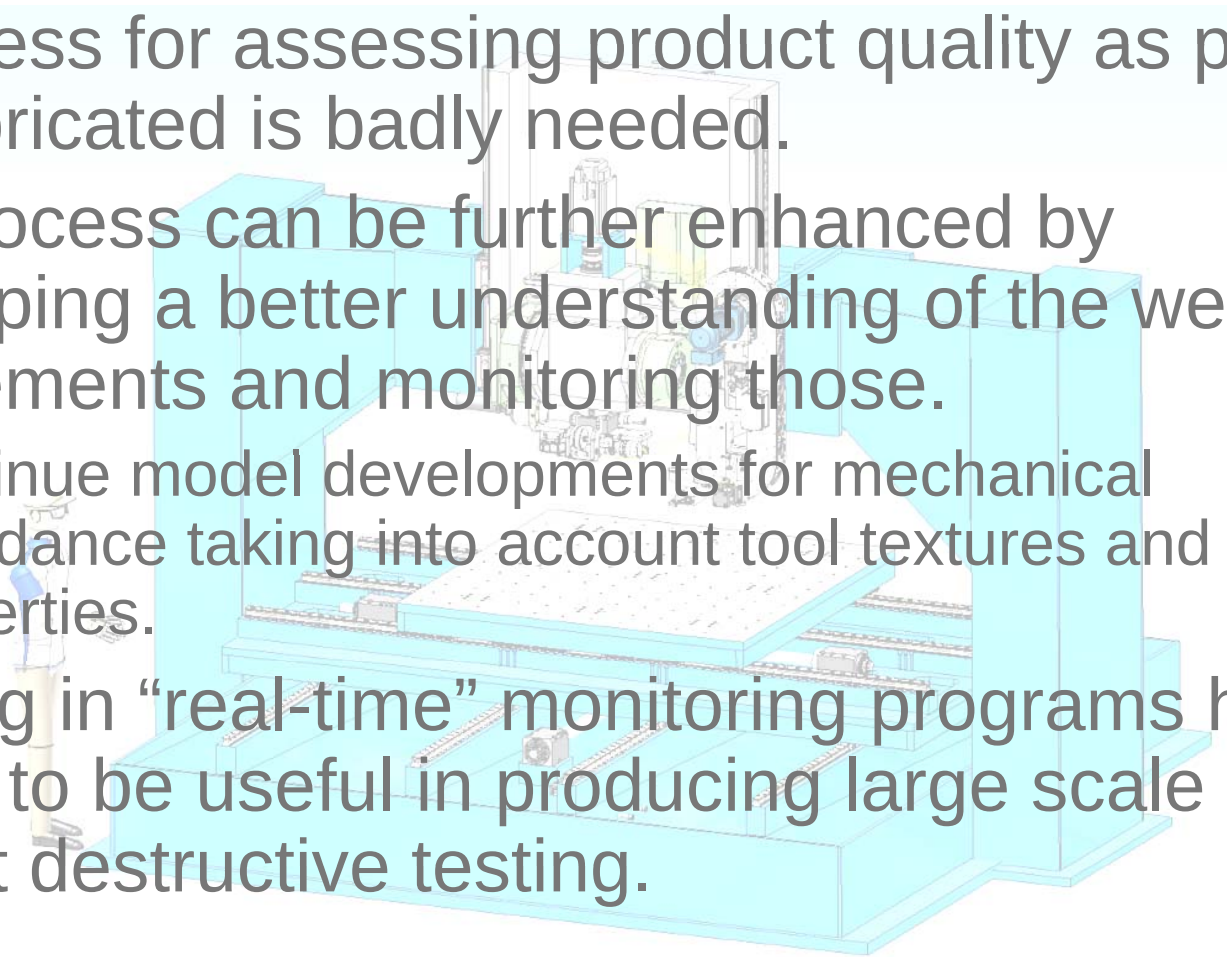






Summary

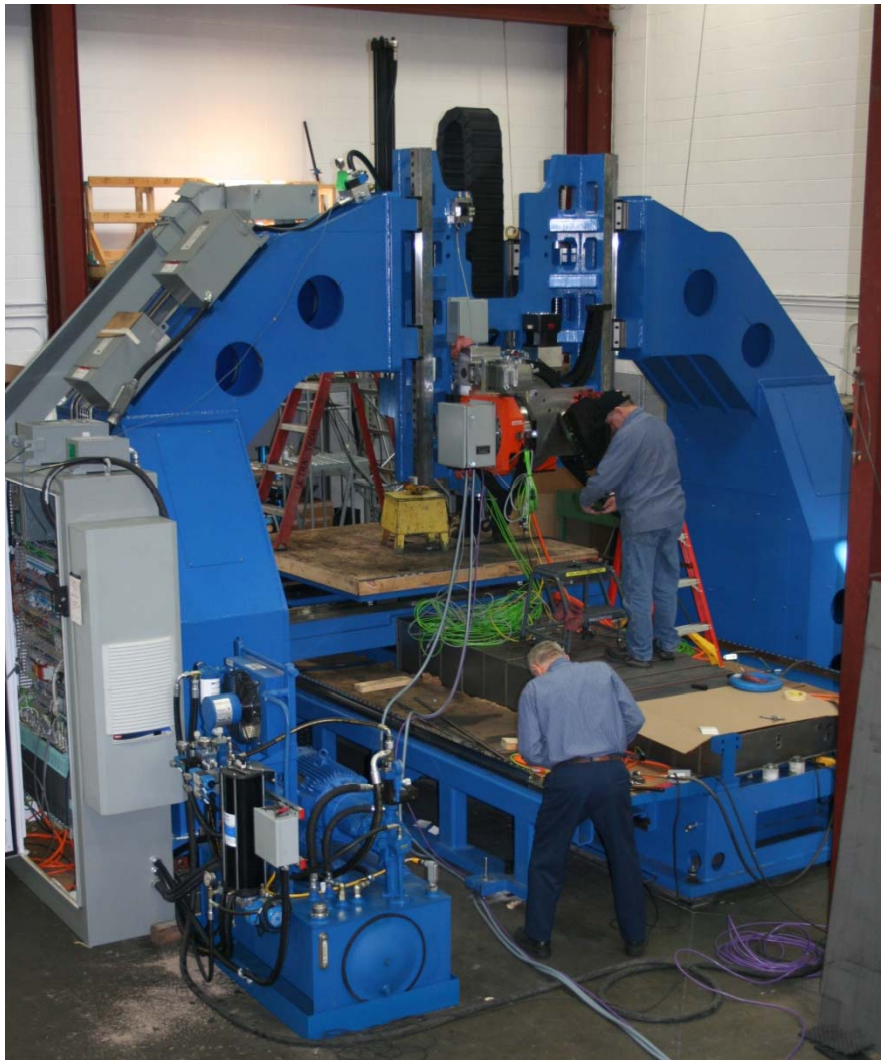
- A process for assessing product quality as parts are fabricated is badly needed.
- The process can be further enhanced by developing a better understanding of the weld requirements and monitoring those.
  - Continue model developments for mechanical impedance taking into account tool textures and material properties.
- Building in “real-time” monitoring programs have shown to be useful in producing large scale parts without destructive testing.



EWI's Next Generation UAM

- Up to 9-kW
- Capable of delivering 7k force
- Welding speeds of 400-ipm

- System online at EWI June of 2010



Celebrating 25 Years of Joining Innovation
EWI 25 YEARS

Questions?

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Ultrasonics

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