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
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 in³ work envelope
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

1 – 2 kW

9 kW ‘Push – Pull’
Supporting Developments

- EWI Solidica System
- VHP Test Bed
- 9 kW Push-Pull
- Booster eliminated
Results with Advanced Materials

[Images of various materials and samples, labeled (1) to (4).]
Issue, Challenge, Question ...

- Can we infer, deduce, measure quality of the weld from power supply power and/or impedance data?
Know that ... UAM is based on US metal welding (UMW)
Modeling Shear Forces

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

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

$$A_W(t) = A_0(1 - e^{-t/T})$$
Knowing Shear Force …

Possible control technology
– Weld impedance \( Z_w = \frac{F_s}{v_s} \).
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?
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
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.

![Graph showing power output over time.]

- Output Power
- Time (sec)

- Power (W x 2)

- 2500
- 1500
- 2000
- 1000
- 500
- 0

- 0 1 2 3 4 5 6

- Time (sec)
Determining bond quality cont.
Determining bond quality cont.
Determining bond quality cont.
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
Questions?

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