EWI®

THE MATERIALS JOINING EXPERTS

EWI
THE MATERIALS JOINING EXPERTS

Use of IR Technology in Sensing and Control of Ultrasonic Metal Welding

Karl Graff, Jay Eastman, Tim Frech, Yu-Ping Yang
Edison Welding Institute
Columbus, Ohio 43221
614.688.5000
karl_graff@ewi.org

US Metal Welding

Transducer
Booster
Horn/Sonotrode
Vibration
Anvil
Workpieces
Power Supply
Static Force

Lateral Drive System

Static Force
Sonotrode
Vibration
Workpieces
Anvil
Weld Zone

Weld zone

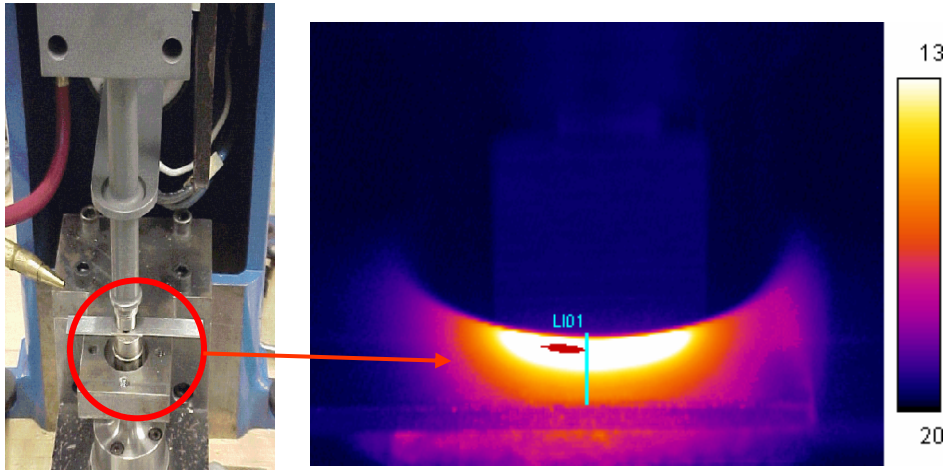
Static Force
Reed/Sonotrode
Transducer
Power Supply
Vibration
Workpieces
Anvil

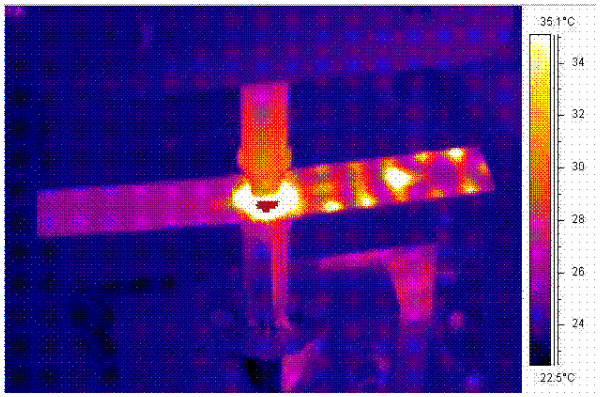
Wedge-Reed System

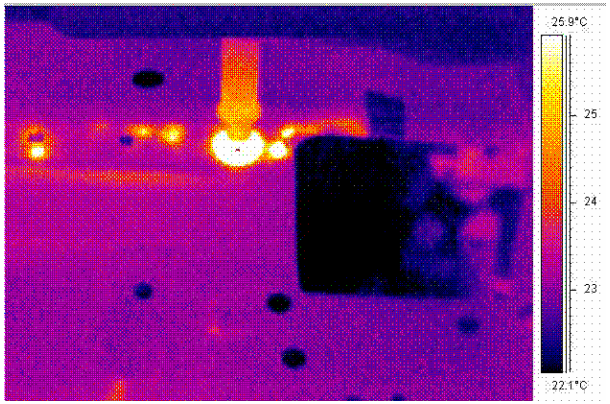
EWI
THE MATERIALS JOINING EXPERTS

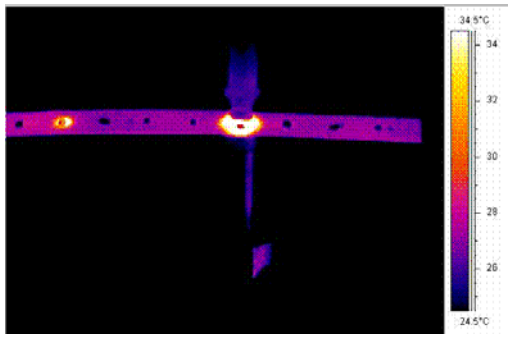
IR - Two Fields of Use in UMW

- Sensing, control of UMW process
- Sensing vibrations created by UMW





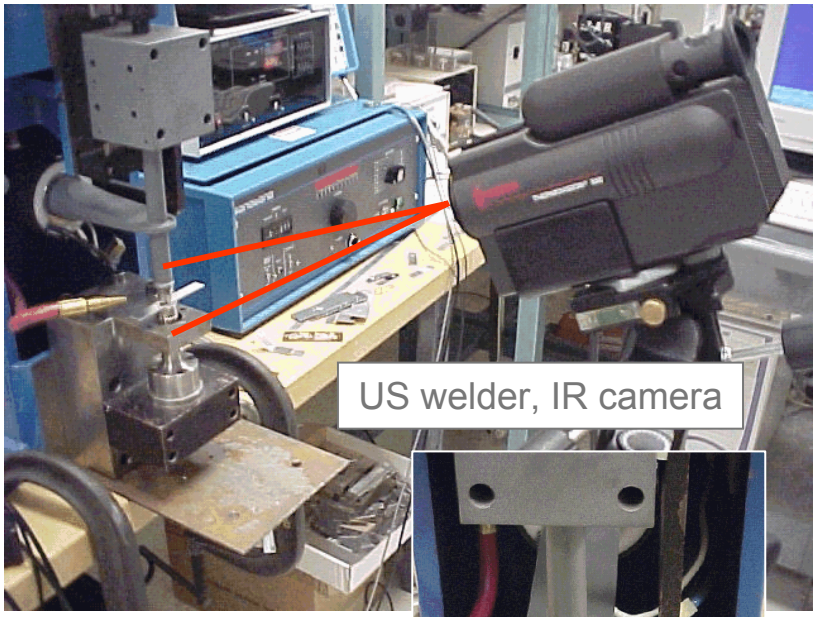


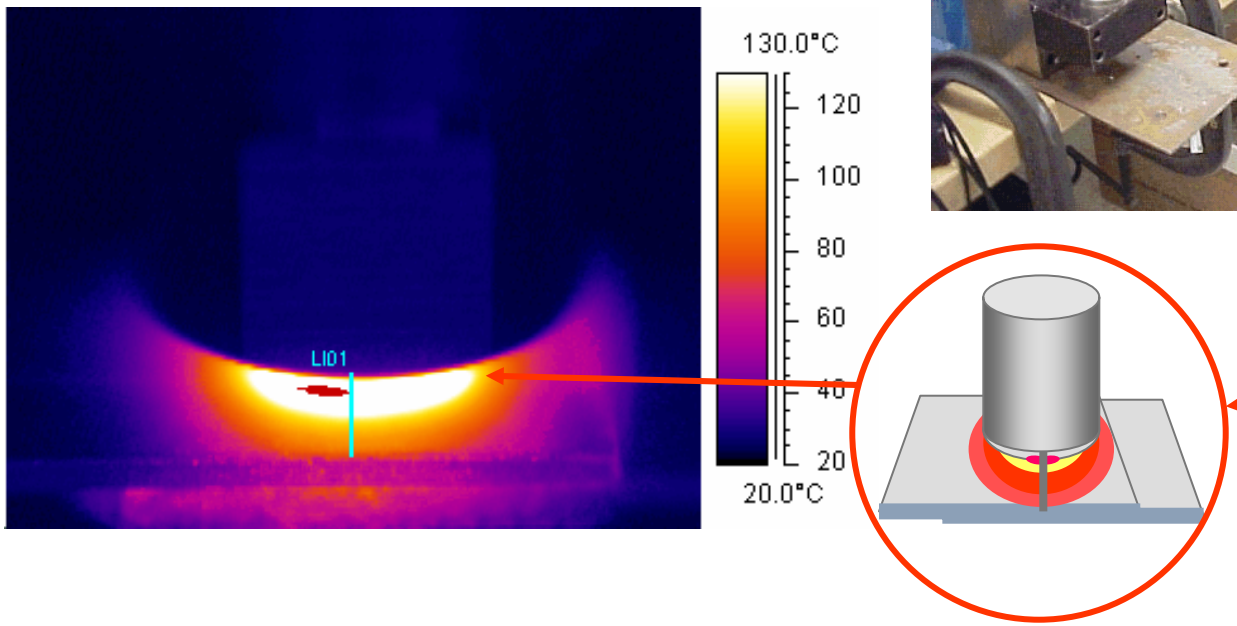


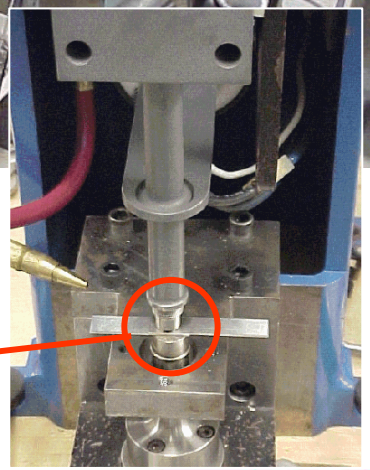
EWI
THE MATERIALS JOINING EXPERTS

Use of IR in Weld Sensing, Control

- Can IR image/profile be related to weld quality? (‘quality’ ~ weld strength)



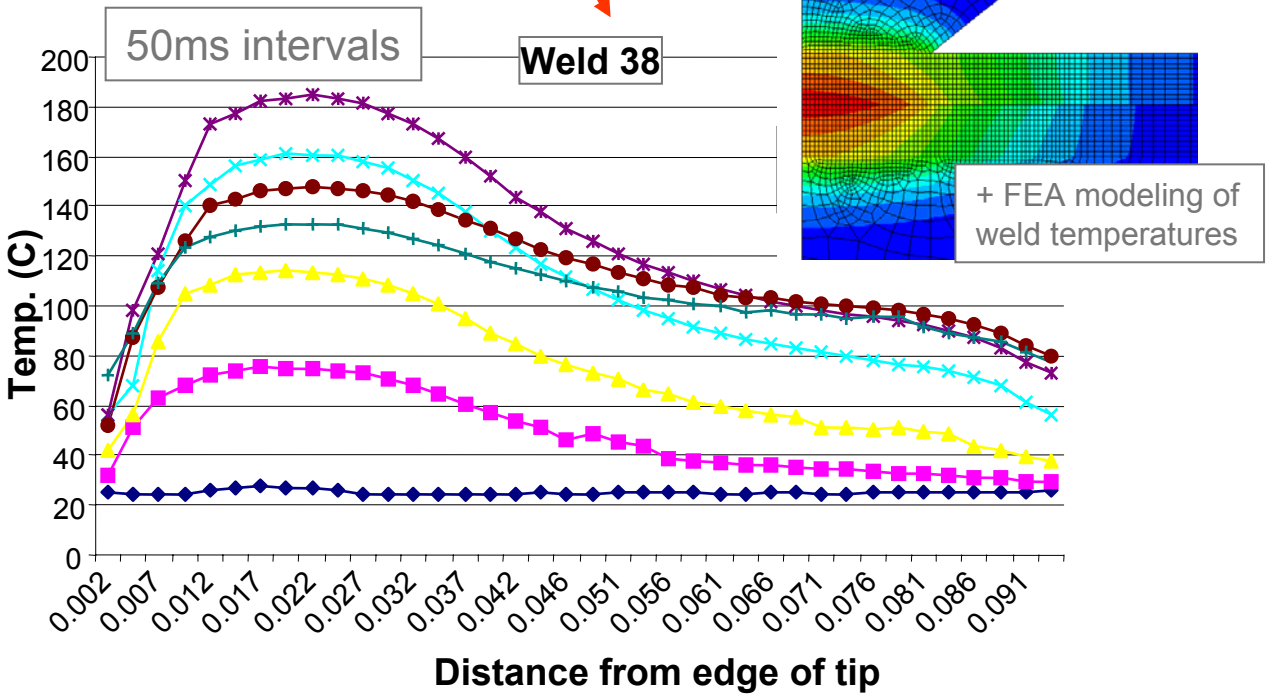




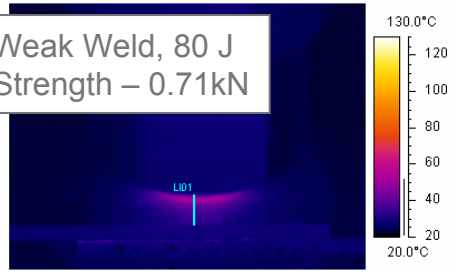
EWI
THE MATERIALS JOINING EXPERTS

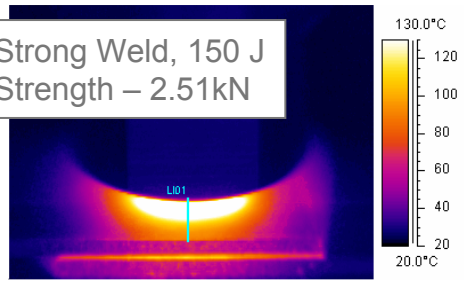
Early IR Weld Sensing Work

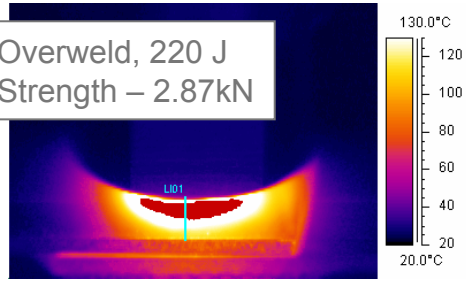
- IR image for various weld energies
- Weld temperature near sonotrode at various times



+ FEA modeling of weld temperatures



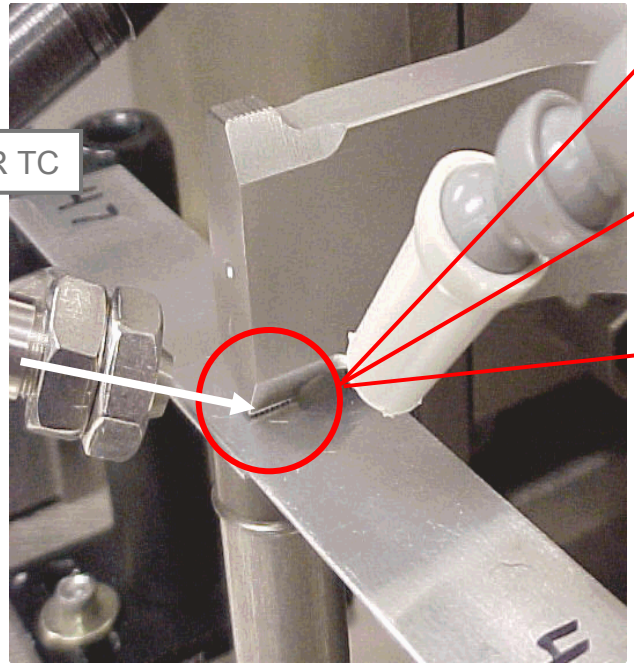


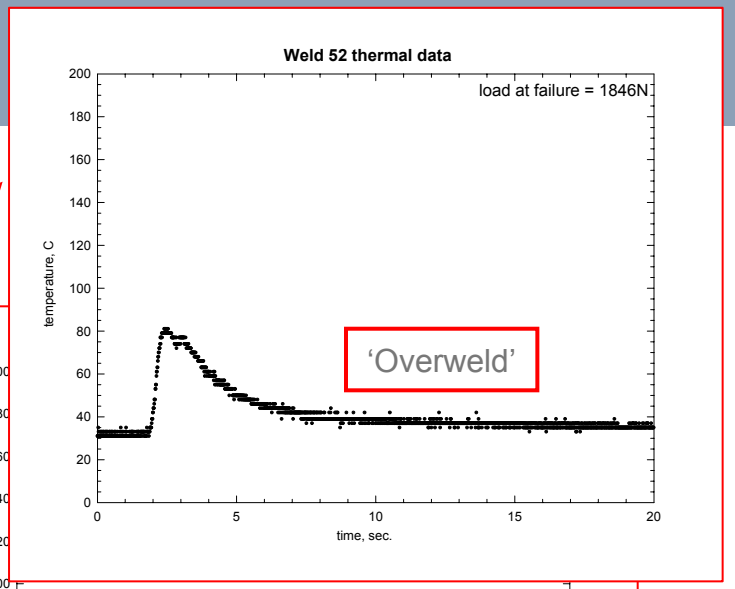


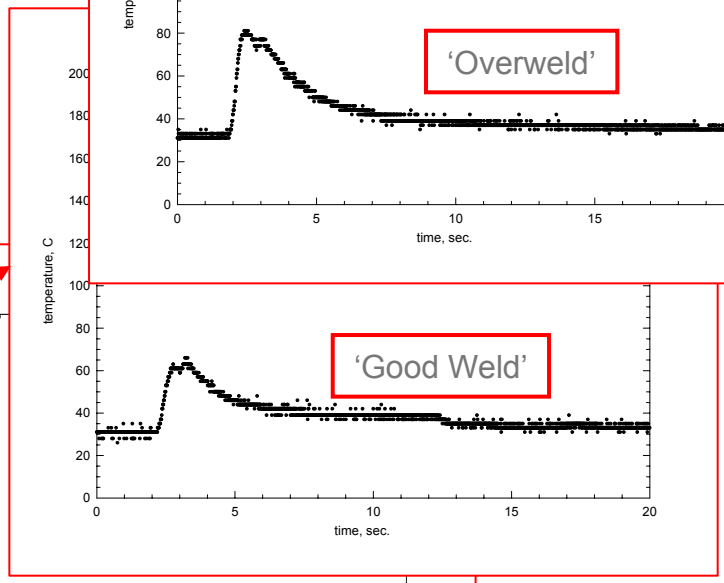
EWI
THE MATERIALS JOINING EXPERTS

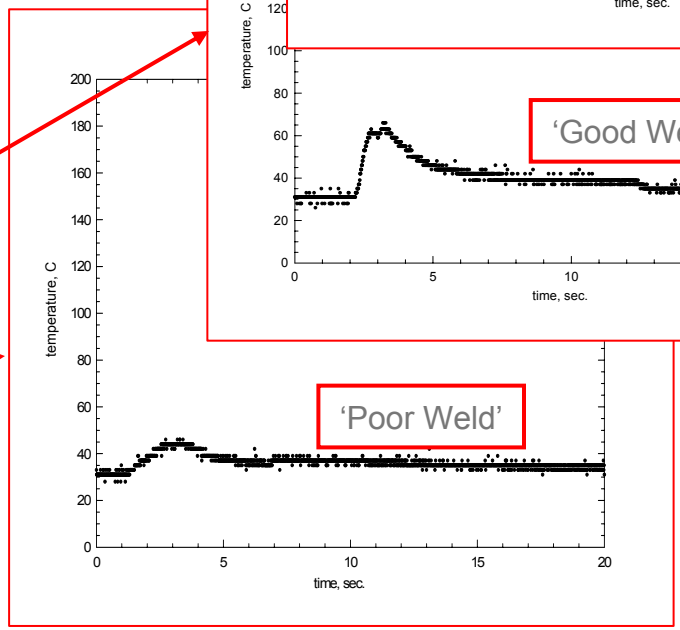
Use of IR TC

- Use IR thermocouple to focus on critical region (determined from IR camera)
- Arrow is line-of sight for IR TC





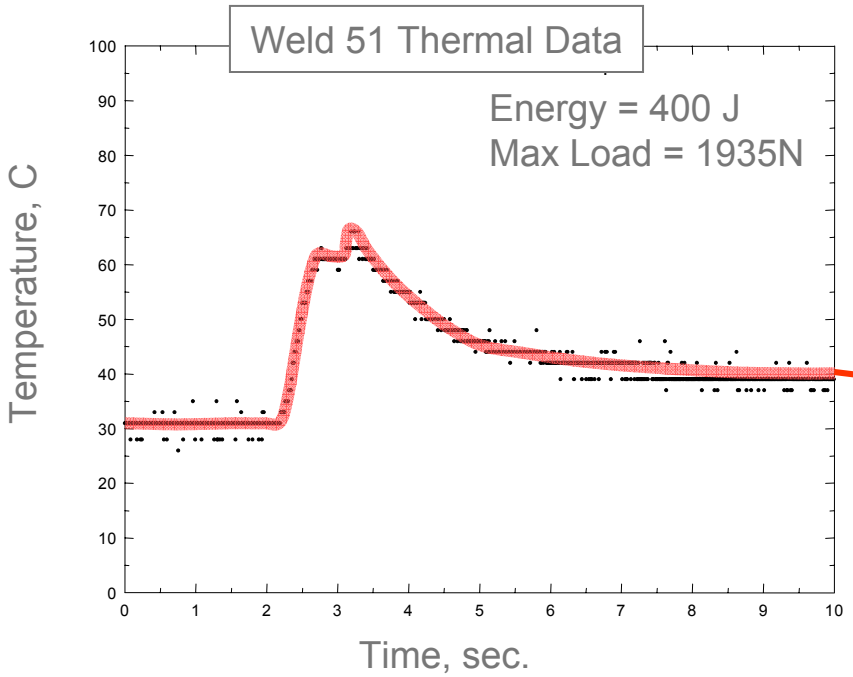




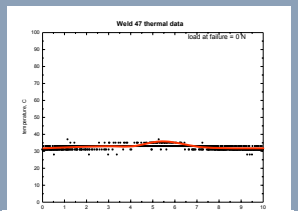
EWI
THE MATERIALS JOINING EXPERTS

Use of IR TC

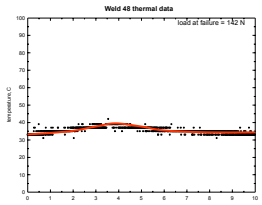
- Progression of temperature and strength with increasing weld amplitude and power (400J ~ constant)



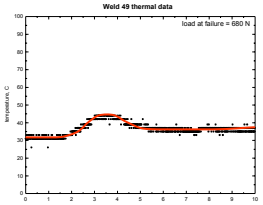
A = 20µ
P = 105W
ML = 0 N



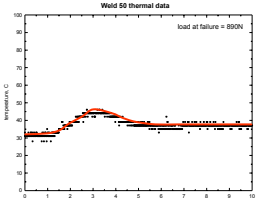
A = 30µ
P = 210W
ML = 142 N



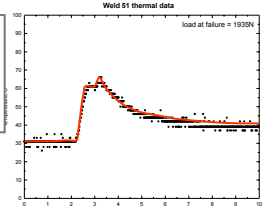
A = 40µ
P = 405W
ML = 680 N



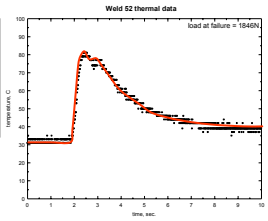
A = 50µ
P = 435W
ML = 890 N



A = 60µ
P = 1110W
ML = 1935 N



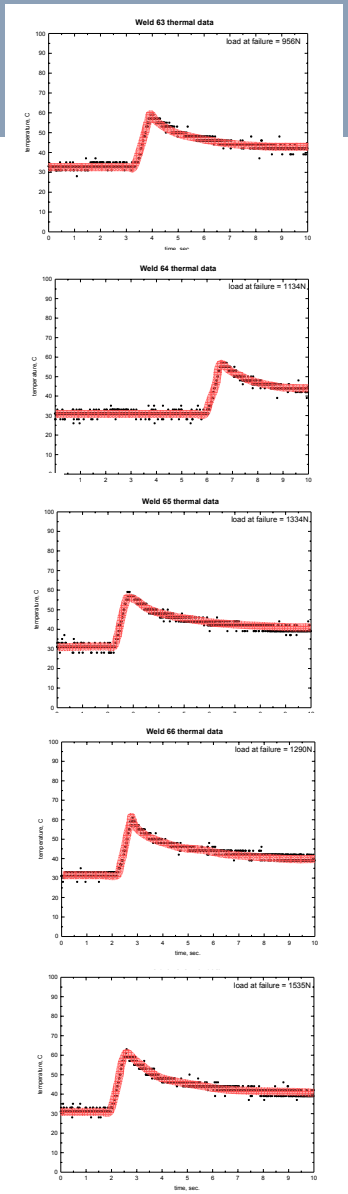
A = 70µ
P = 2055W
ML = 1846 N



EWI
THE MATERIALS JOINING EXPERTS

Use of IR TC

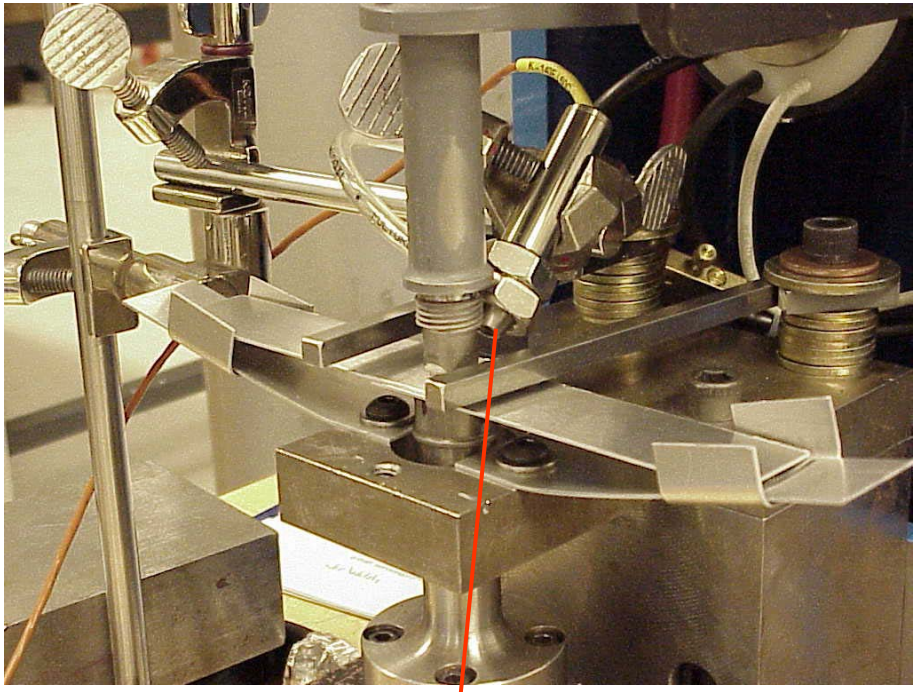
- Temperature repeatability – 5 welds (400J, 60µ, 1250N average, Std. dev. 218N)
- Weld temperature correlates with weld strength
- Potential for on-line weld quality measurement



EWI
THE MATERIALS JOINING EXPERTS

IR TC – Recent Work

- **Sonobond Model 2016 Welder**
- **Material:** 25 x 100mm x 0.9-mm 6111 Aluminum
- **Varied Power:** 1500 and 2000 W
- **Varied Time:** 0.44, 0.66, 0.88 S
- **Varied Pressure:** 344, 448, and 551 MPa
- **Made 3 Welds at Each Setting (54 welds)**
- **Recorded IR TC Signature of Each**



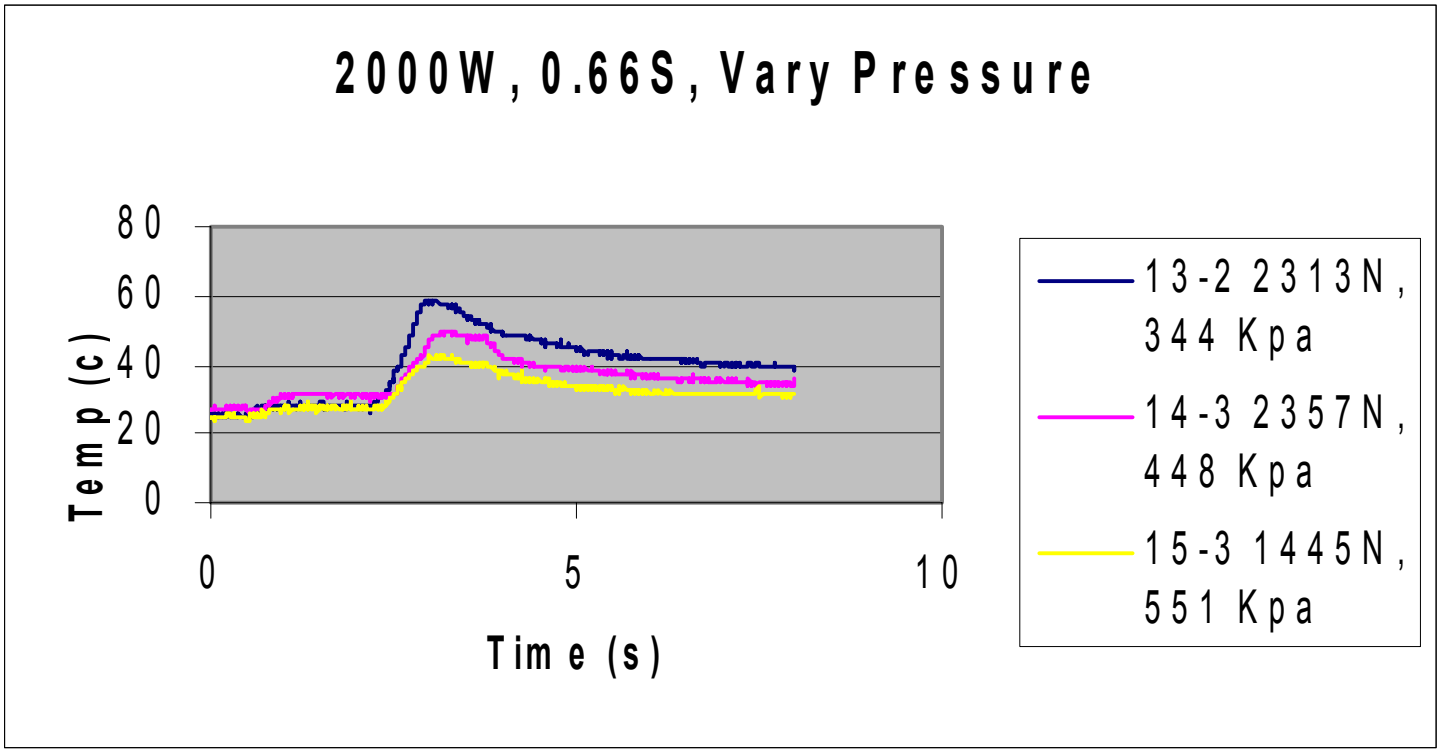
EWI
THE MATERIALS JOINING EXPERTS

Typical IR TC Data

13-2

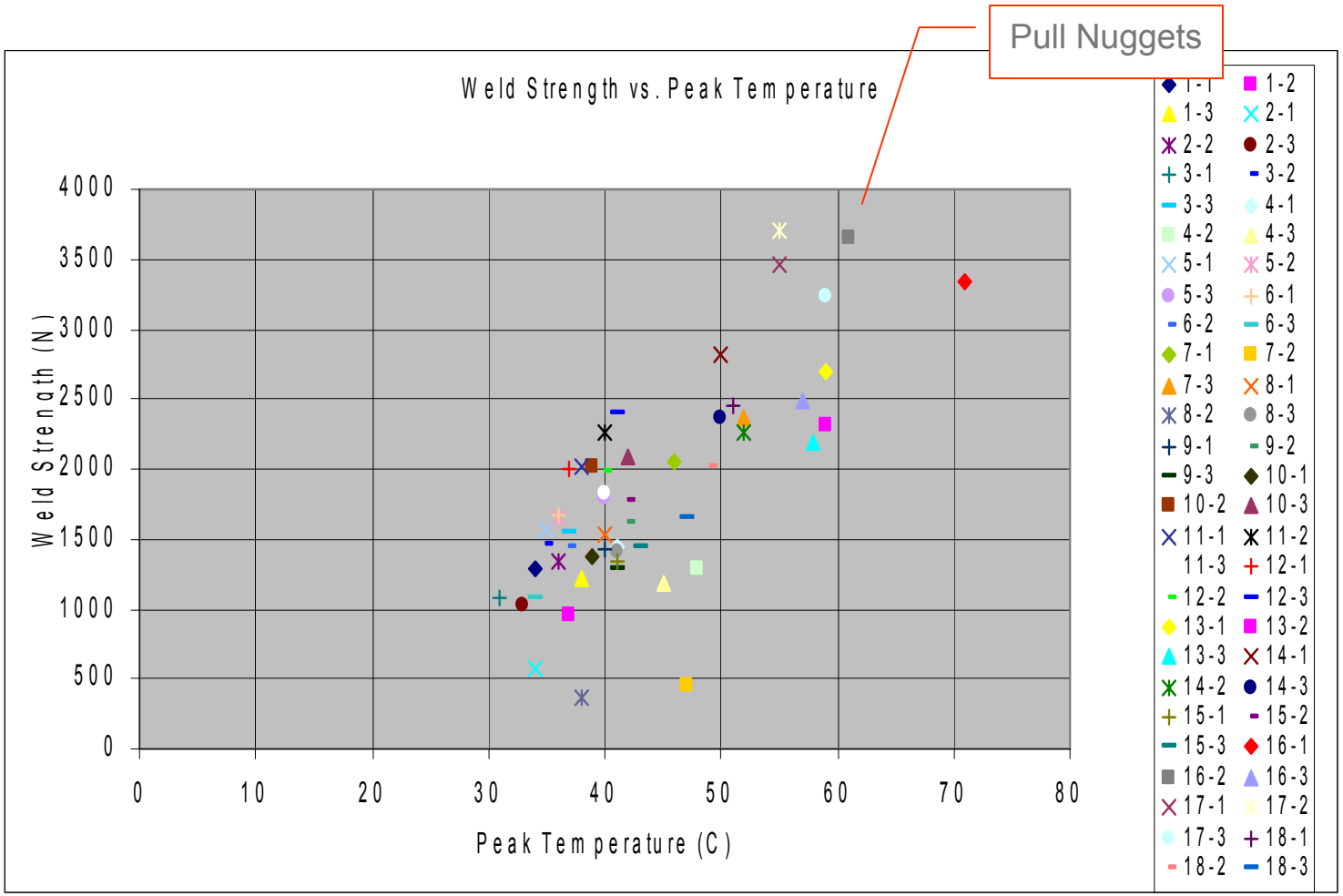
14-3

15-3



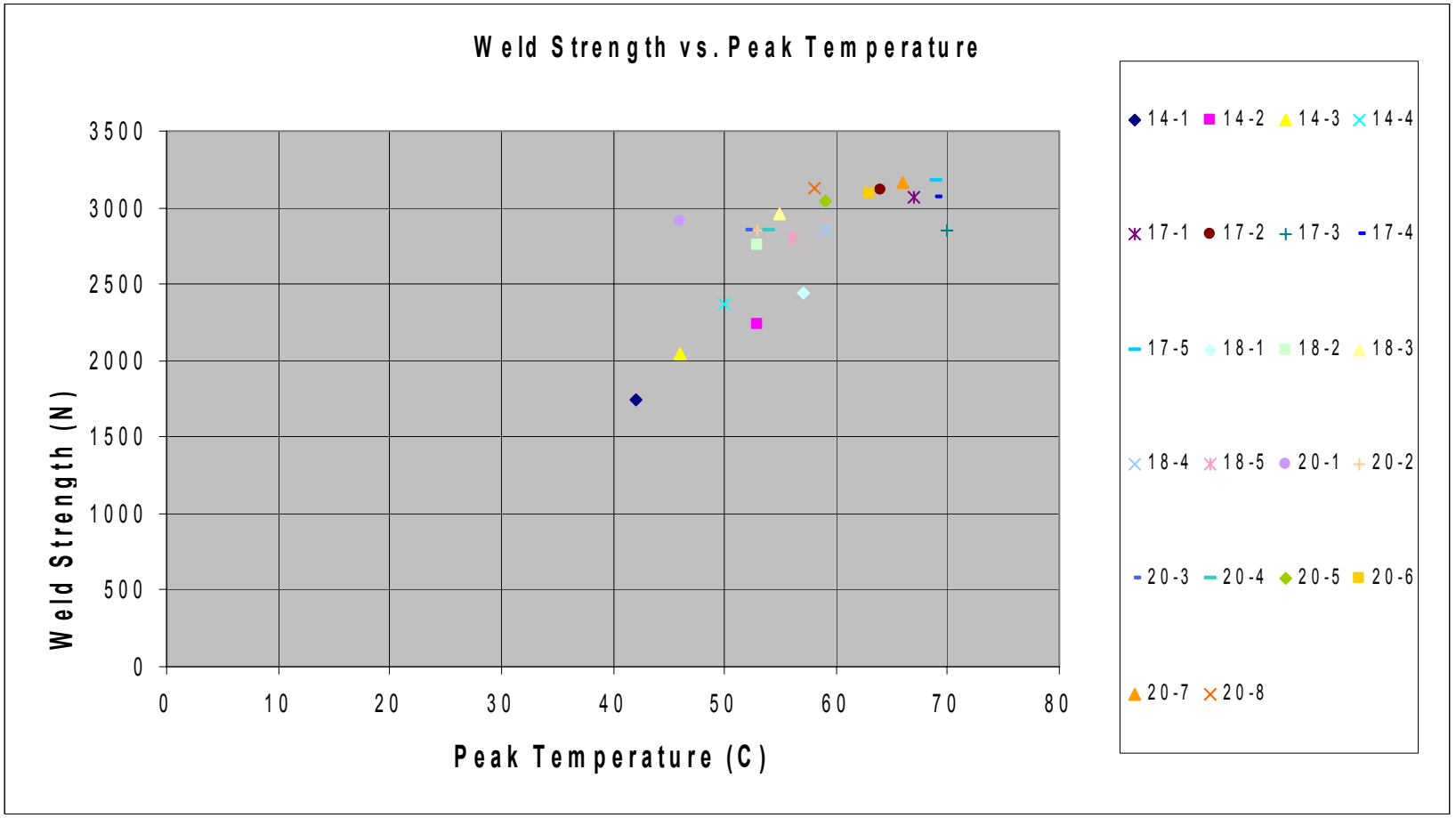
EWI
THE MATERIALS JOINING EXPERTS

Weld Strength - Peak IR Temperature



EWI
THE MATERIALS JOINING EXPERTS

Repeat Low, Medium, High Settings



EWI
THE MATERIALS JOINING EXPERTS

Example: Setting Temperature Limits

No Light: Did not reach Minimum Temperature

Green Light: Reached Minimum Temperature

Blue Light: Exceeded Maximum Temperature

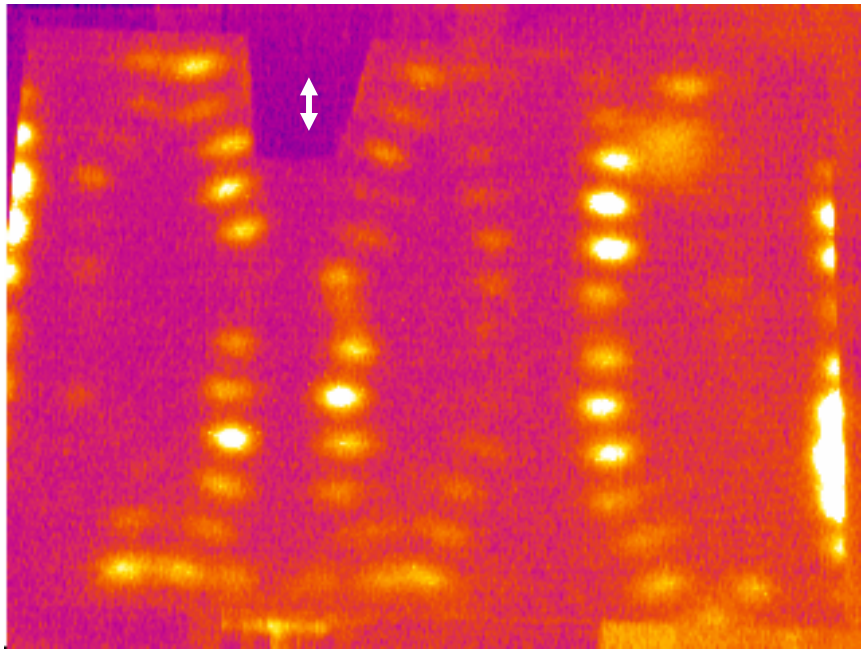
EWI
THE MATERIALS JOINING EXPERTS

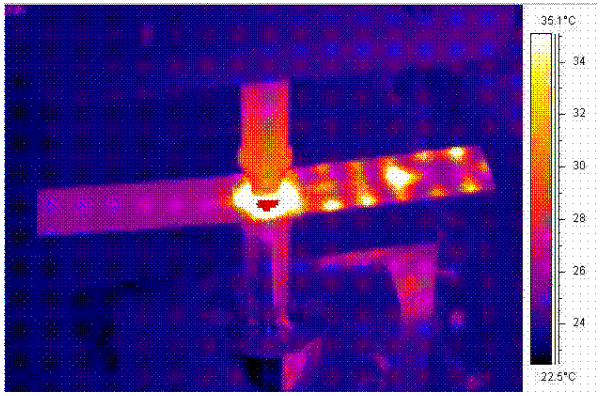
Observations

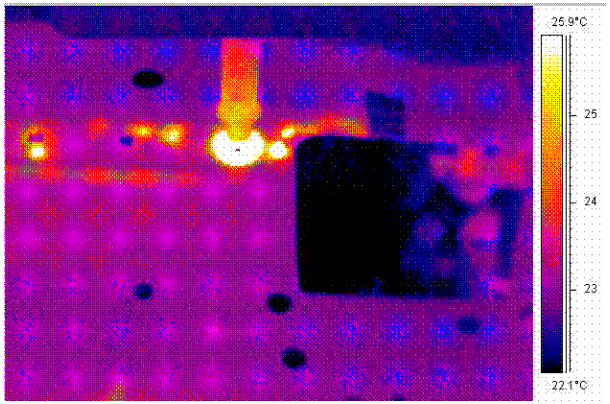
- The higher the observed temperature the higher the tensile strength
- Increasing pressure decreases observed temperature
- Increasing time and power increase observed temperature
- Higher temperatures observed in rapid sequence welding

IR Sensing of UMW Vibrations

- Early work
- Work on large plates

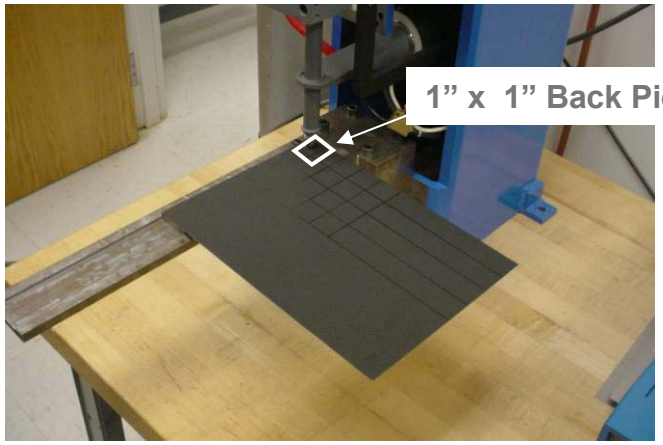






EWI
THE MATERIALS JOINING EXPERTS

Initial Plate Tests



Grid of 20 Weld Locations – ¼ of Plate

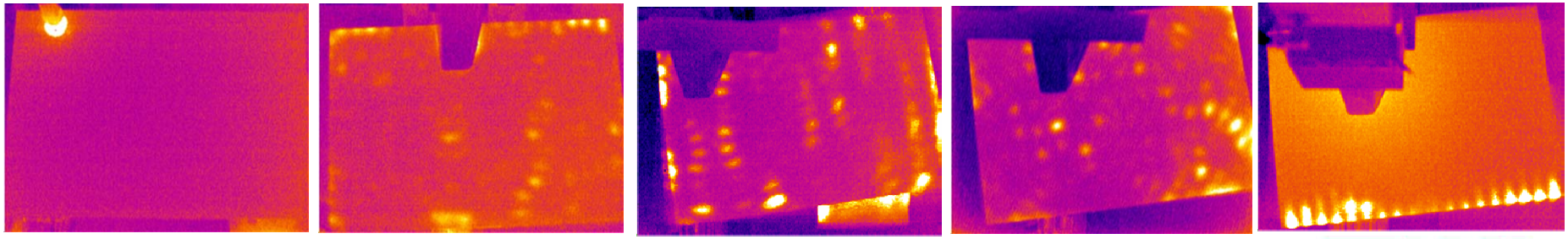
Case modeled by FEA

AA	AB	AC	AD	AE					
BA	BB	BC	BD	BE					
CA	CB	CC	CD	CE					
DA	DB	DC	DD	DE					

6111 aluminum
0.9-mm thick

All Plates 200 mm x 280 mm
divided into approximately 25-mm squares

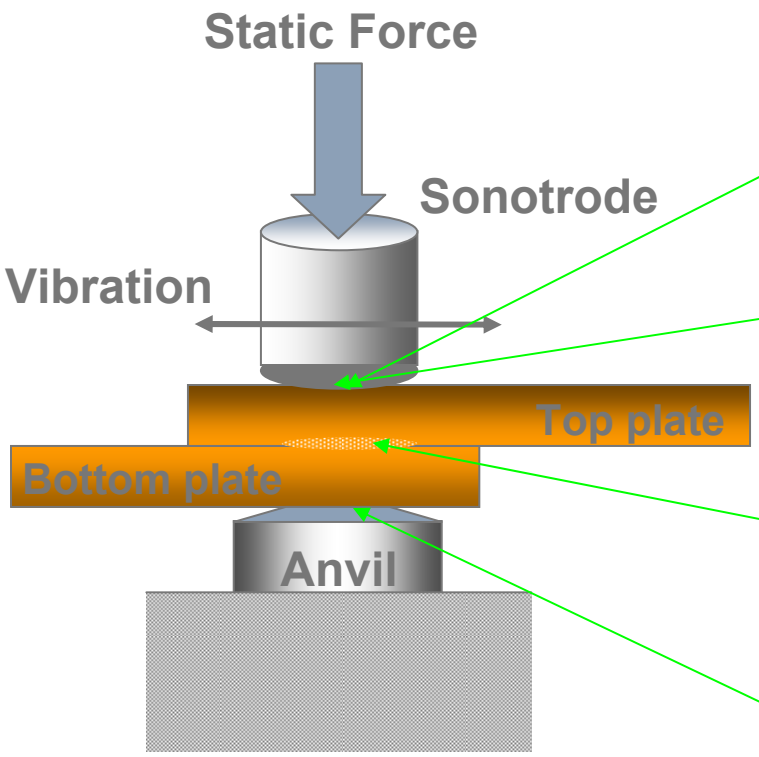
AB AE BB BD CD



Thermography results

EWI
THE MATERIALS JOINING EXPERTS

FEA Modeling of UMW Plate Vibrations



Static Force was modeled by applying a pressure

Interaction between the sonotrode and the top plate was modeled by applying nodal displacements.

Interaction between the two plates was modeled by contact simulations.

Interaction between the bottom plate and the anvil was modeled by fixing the interface surface.

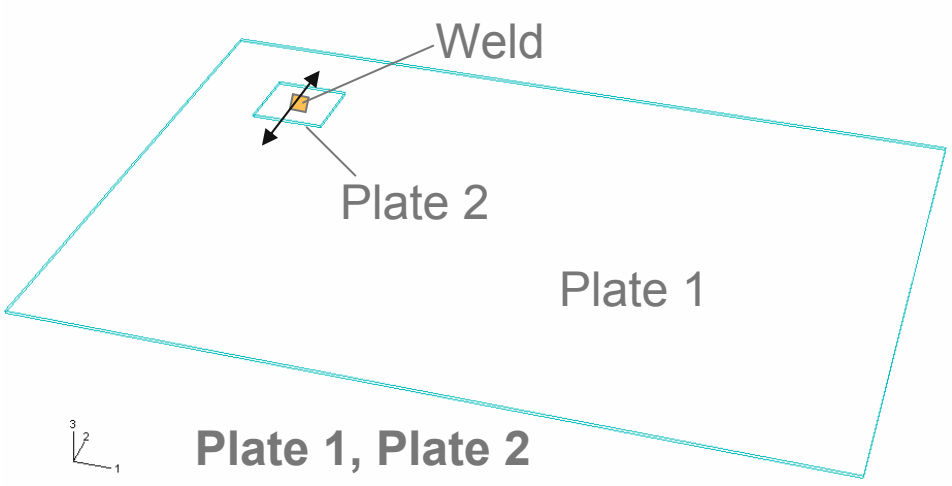
Two stages in ultrasonic welding:

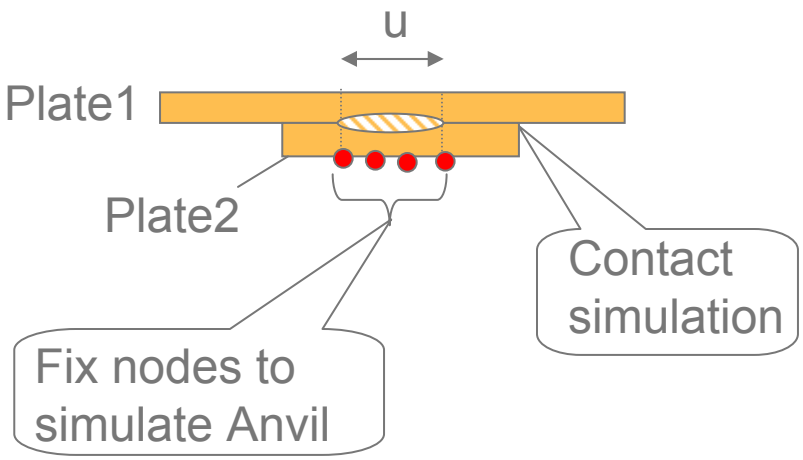
Stage 1: Sliding of plate 1 on the Plate 2

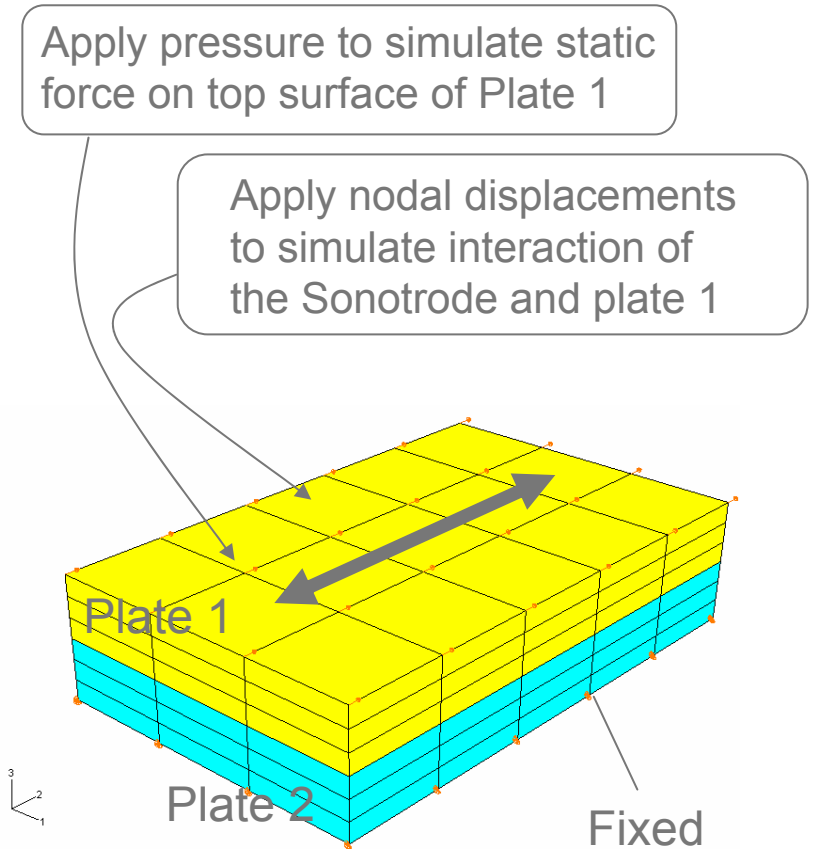
Stage 2: weld formation

EWI
THE MATERIALS JOINING EXPERTS

FEA Model of Plate Vibrations







Finite Elements in weld area

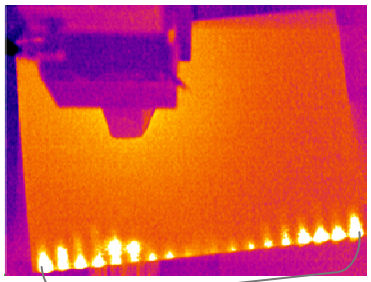
EWI
THE MATERIALS JOINING EXPERTS

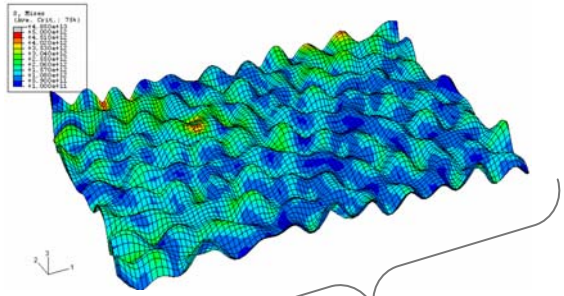
Experimental, Modeling Results

Thermography results

Modeling

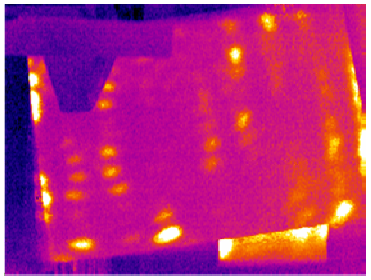
CD

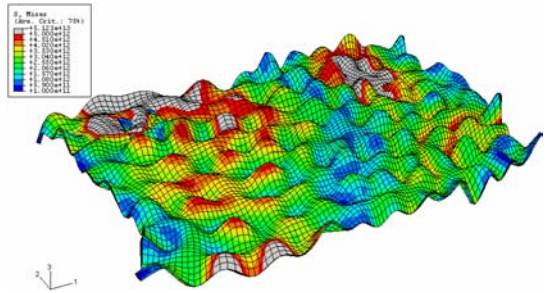




Similar edge waves were observed

BB

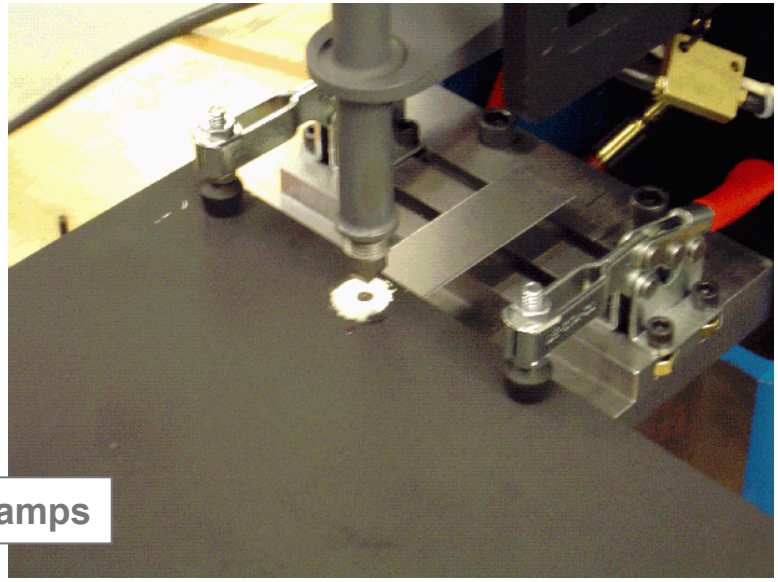




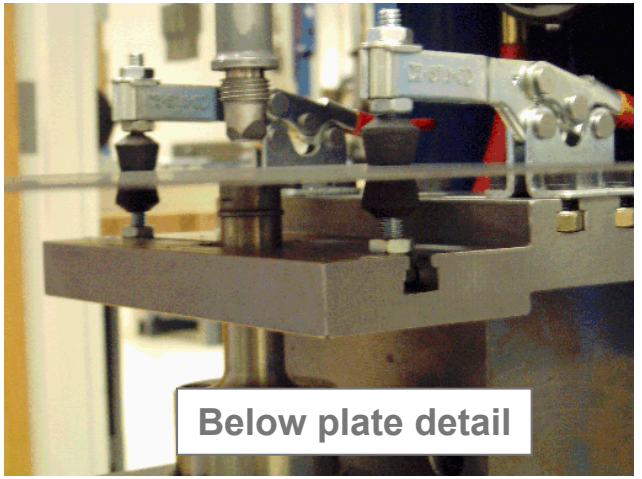
High temperature spots ⟷ **High stress spots**

EWI
THE MATERIALS JOINING EXPERTS

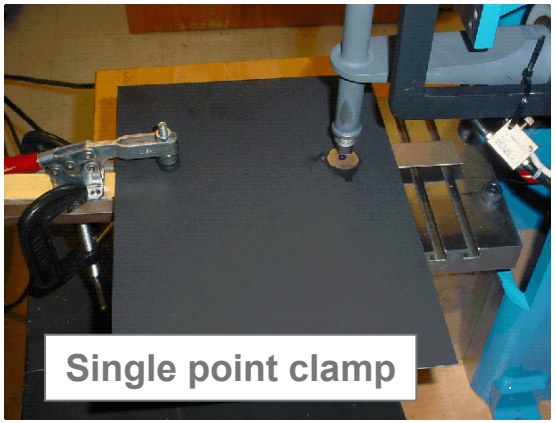
Effects of Clamping



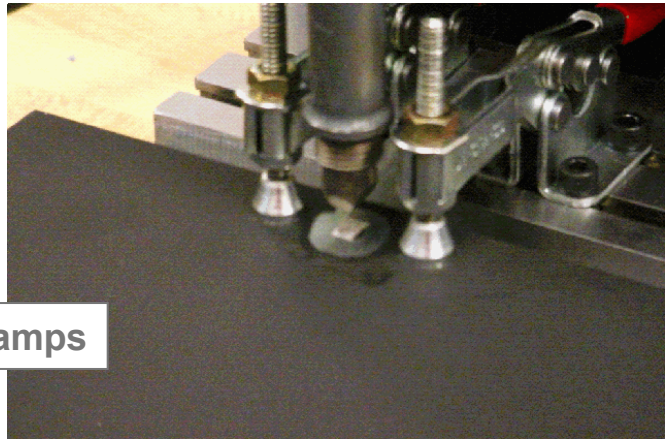
Rubber tip clamps



Below plate detail



Single point clamp

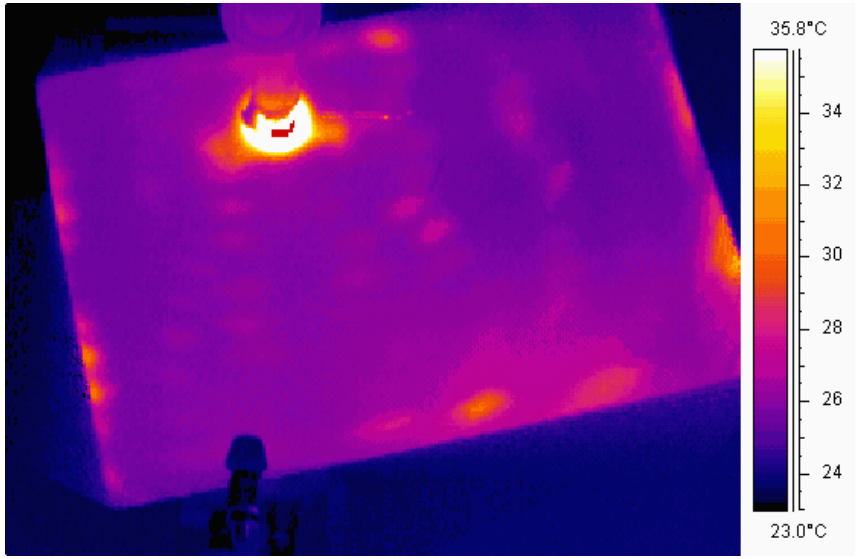


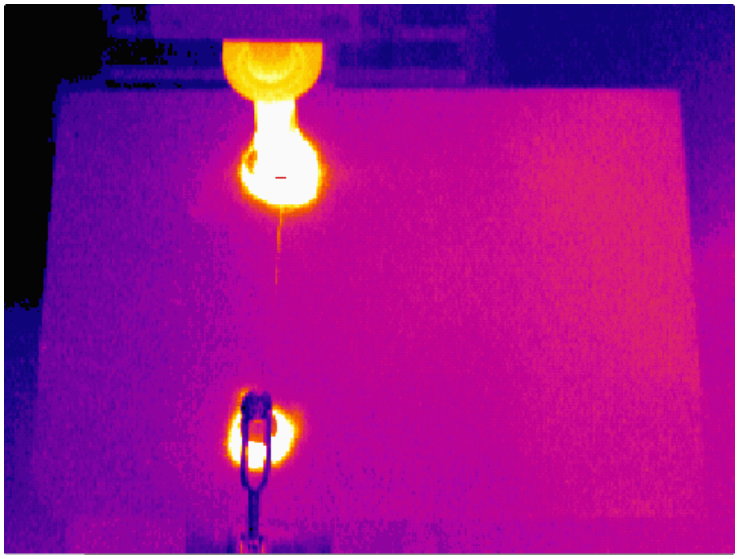
Metal tip clamps

EWI
THE MATERIALS JOINING EXPERTS

No Clamp vs. Clamp

- Effect of single point clamp

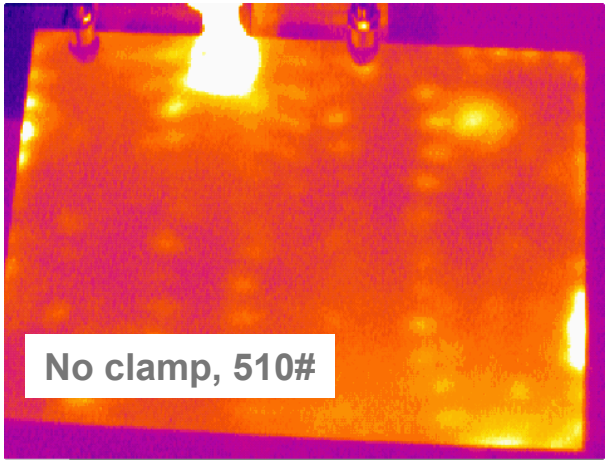


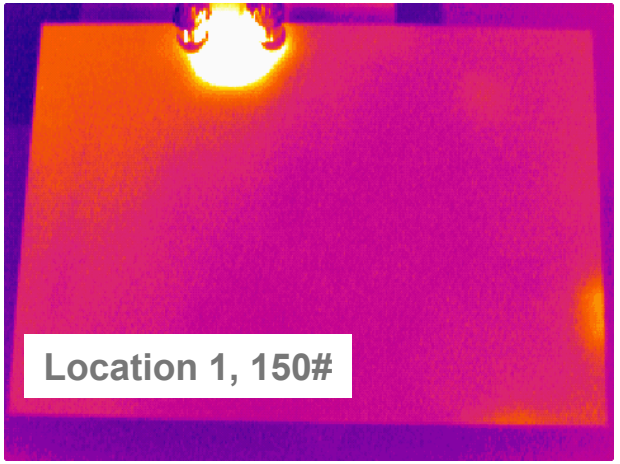


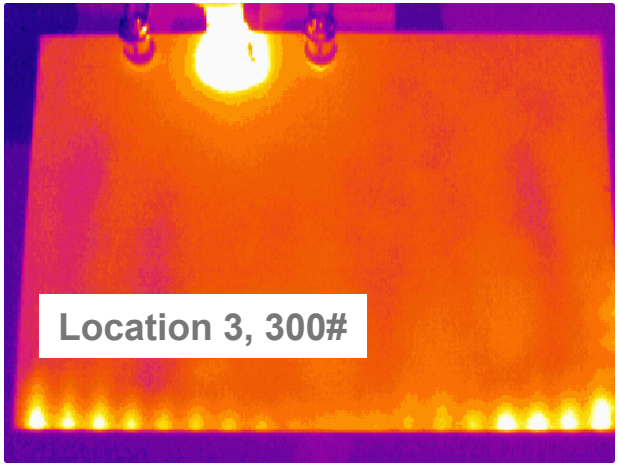
EWI
THE MATERIALS JOINING EXPERTS

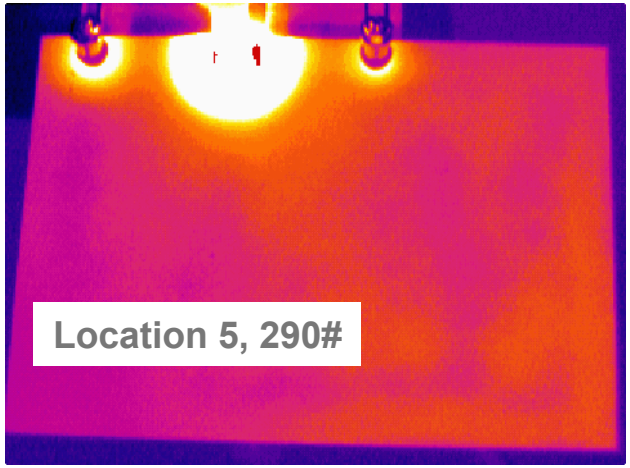
Rubber Tip Clamps - AD

- Weld at AD, various clamp locations, strengths





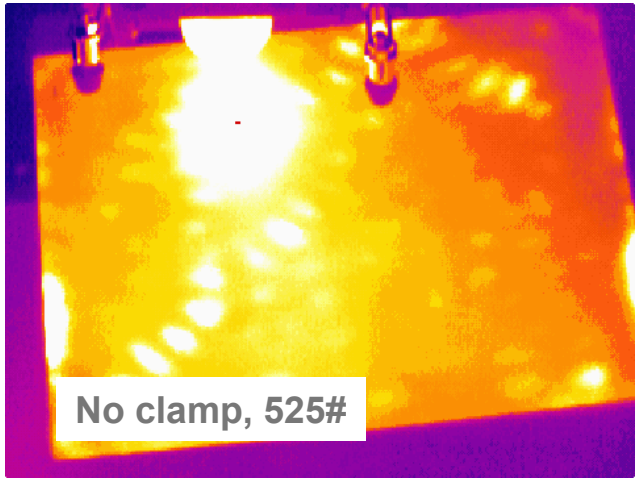


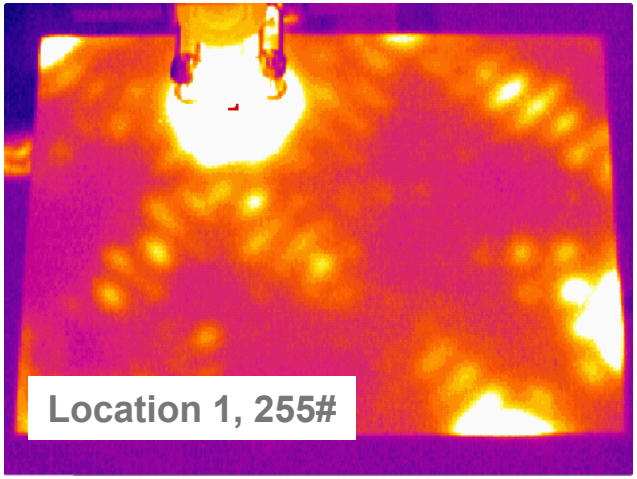


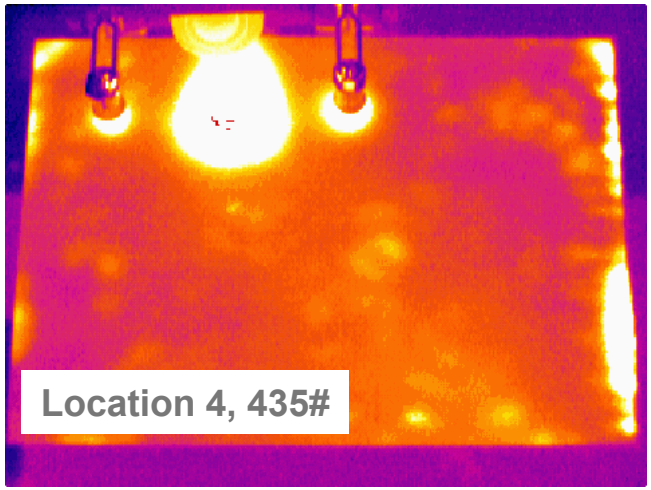
EWI
THE MATERIALS JOINING EXPERTS

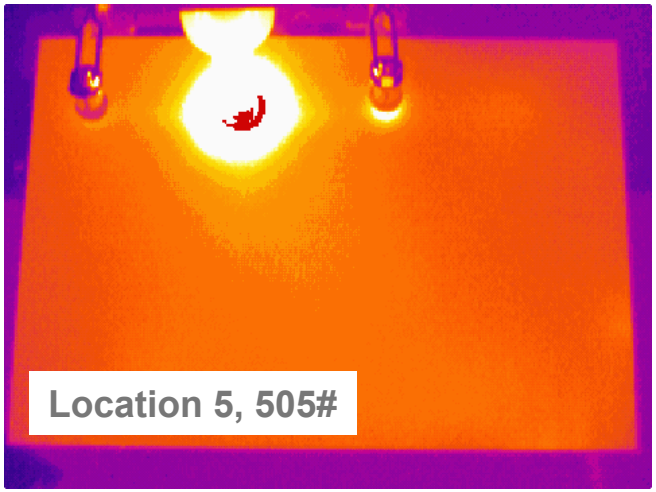
Rubber Tip Clamps - BD

- Weld at BD, various clamp locations, strengths









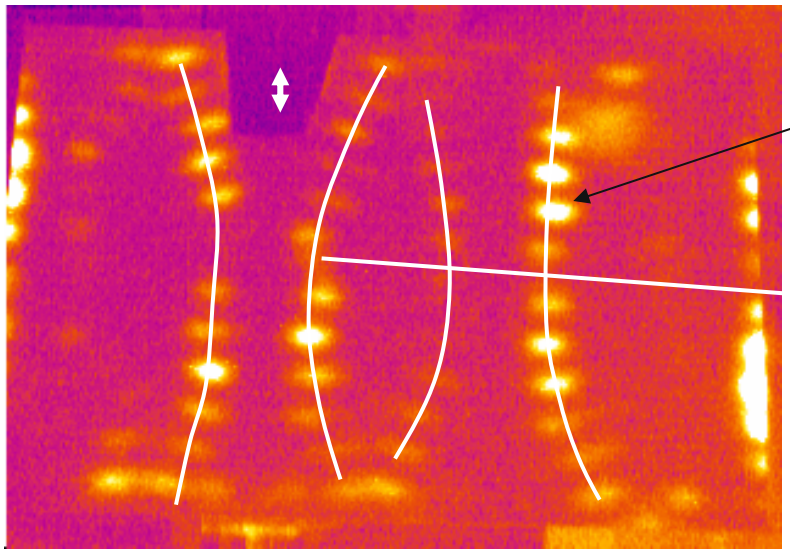
EWI
THE MATERIALS JOINING EXPERTS

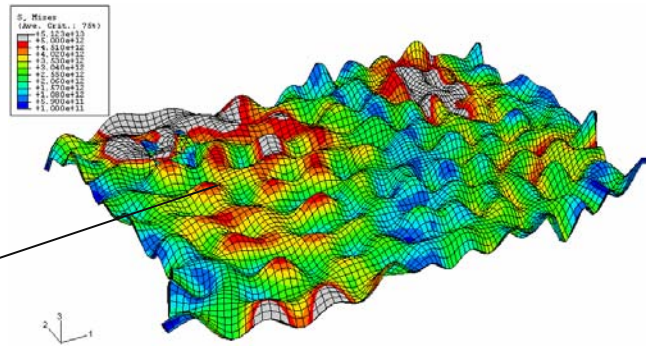
Observations

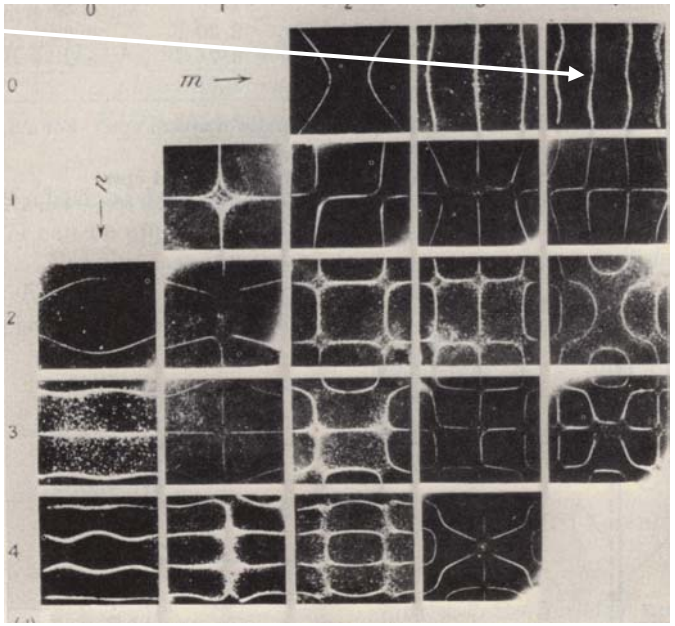
- Variability of IR images, strengths for “identical welds”
- Variability of strengths by weld location (AD, BD, etc)
- Modeling shows well known variations in driving impedance (this has also been modeled)
- Modeling shows HF modes – but images more complex

Note on Complex Mode Shapes

- FEA show HF modes







- Audible subharmonics generated during welding - show up with HF superimposed

EWI
THE MATERIALS JOINING EXPERTS

EWI
THE MATERIALS JOINING EXPERTS

Questions

Karl Graff
Microjoining & Plastics

614.688.5000
karl_graff@ewi.org

EWI®

THE MATERIALS JOINING EXPERTS