Welding and other applications of the Vaporizing Foil Actuator (VFA) tool

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Outline

• Impulse manufacturing lab
• Impact welding (Vaporizing Foil Actuator Welding)
• Other applications
  – Cutting
  – Shape calibration
Impulse Manufacturing Lab

• Moving materials at strain rates > 1000/s
• Speeds > 100 m/s
• By electromagnetic induction, laser ablation and vaporizing foil actuator
• Weld, form and cut materials, mostly metals
• 5 capacitor banks: 1 kJ to 48 kJ
• 3 PDVs measuring velocities from 1 m/s to 2 km/s on up to 16 channels

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Impact welding

• Solid-state welding by means of a high-speed, oblique impact.
  – Critical parameters
    • Speed: typically about 300~1000 m/s
    • Angle: typically about 5°~30° (must be > 0°)
  – Traditionally done by using explosives and later, magnetic pulse

Cons: Explosive! Actuator longevity!
Vaporizing Foil Actuator Welding

NOT MPW

Capacitor Bank

aluminum foil actuator

100 kAmps

vaporized foil

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Welding Procedure

Vaporizing foil actuator
VFAW shapes

Area weld
8 kJ

Spot weld
2.6 kJ energy VF

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Current, Voltage and Velocity

Foil burst time

Current (kA)  
Flyer velocity (m/s)  
Voltage (V)

Time (µs)

0  5  10  15  20  25
High Velocity Impact Welding of CP-Ti/Cu 110

Impact Velocity: 770m/s

Impact Angle: 24°
VFAW combinations

- AA6061-SS304
- AA6061-Cu
- Cu-1018 steel
- Cu-CP Ti
- Cu- Zr BMG
- Cu-17F W alloy
- AA6061-AZ91D
- CP Ti-1018 steel

and a few more…
VFAW-ed combinations

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Peel strength > 250 N/mm
5052-H32 welds: Comparison to FSSW

Lap shear tests

All welds created with 600 J

AA5052/AA7075 results: Mechanical Tests

- 5052 thickness: 2 mm
- 7075 thickness: 2.3 mm
- Input energy: 4 kiloJoules
- Impact velocity: 580 m/s
- Spot size: 15 mm
- Samples left a nugget
AA5052/AA7075 results: Microanalysis

- Strength of base material retained
- Negligible thinning
- Wavy interface
Aluminum-steel welding

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Present: Pedestal system

<100 decibels, 20 second cycle time
Current Collaborations on VFAW

• **OEM:** Honda, others
• **Tier 1:** Magna, Jefferson Industries
• **Equipment builder:** Coldwater Machine
• **Materials:** Alcoa, Meridian, Ashland
• **Modeling:** UNH, OSU SIM Center, PNNL
• **Training:** Tri-Rivers Center

Collaborators:
- Tim Abke (Honda)
- Duane Detwiler (Honda)
- Pete Edwards (Honda)
- JK Hong (Battelle)
- Marc Auger (Magna)
- Michael Barker (Ashland)
- Matt Brienzo (JIC)
- Dan Bryant (Alcoa)
- Jen Locke (OSU)
- Jason Johnson (OSU)
- Erman Tekkaya (TU)
- Tim Abke (Honda)
- Christian Weddeling (TU)
- Marlon Hahn (TU)
- Anthony Luscher (OSU)
- Suresh Babu (UTK)
- Curtis Prothe (DMC)
- Brad Kinsey (UNH)
- Xin Sun (PNNL)
- ….and many others
Other applications

• Forming
• Cutting
• Shape calibration
• Conformal/Interference fits
Other applications

• Forming
• Cutting
• Shape calibration
• Conformal/Interference fits
22MnB5 shearing using VFA

1.5 mm thick 1500 MPa boron steel
22MnB5 shearing using VFA

- Uniaxial tension
- Low-cycle fatigue
  - 10 Hz, 50% ultimate failure load

<table>
<thead>
<tr>
<th>Cutting method</th>
<th>Cycles to failure</th>
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<td>VFA shear</td>
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<tr>
<td>Water jet</td>
<td>6131</td>
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VFA Shape Calibration Process

1. Pre-form as received sample to target shape using a hydraulic press

2. Calibrate using Vaporizing Foil Actuator Method

- Insulated Preformed Sample
- Punch
- Backing Block
- Die
- Backing Block
- Hydraulic Press
- Vaporizing Foil

Sample

Preformed

Shocked

Al - 6061

Steel - 590

Ti - 64

Preformed

Shocked w/o gap 6 kJ
Shocked w/o gap 8 kJ
Shocked w/ gap 6 kJ
Shocked w/ gap 8 kJ

Ti - 6242
More calibrated shapes

Titanium

Grade 2 CP Ti: 0.9mm thick

Uncalibrated

Calibrated at 10kJ

3”

DP 980 Steel

DP780 steel: 1 mm thick

Uncalibrated

Calibrated at 10kJ

3”

T6 6061 Al

AA6061 T6: 1mm thick

Uncalibrated

Calibrated at 6kJ

3”
Study of Springback Relief Mechanism

1. Pre-form as received sample to a semicircular shape using a hydraulic press. Tonnage = 10 US tons

2. Flatten the pre-formed sample using a hydraulic press. Tonnage = 20 US tons

3. Recalibrate/Flatten using VFA, at 3 energy levels: 5 kJ, 8 kJ, 11 kJ

4. Measure Residual Stresses at different stages using Laser XRD

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Top View of Samples

VFA/Shock Energy ↑ Residual Stresses ↓ Springback ↓
Key takeaways

- Similar and dissimilar combinations
- 6mm thick aluminum
- Flange width 10mm with aluminum
- Aluminum welding: reliable

- Current status: Pedestal system
- Well-supported by state, federal and industry projects
- Key strategic partners engaging

- SPH-based simulations
- Also useful for springback removal and cutting of high strength materials
Questions

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