Rapidly Vaporizing Conductors for Impulse Metal Working

04/25/12

Anupam Vivek,

Geoffrey Taber, Jason Johnson, Conner Slone, Katrina Boos, Nolan Windholtz, Glenn Daehn
motivation and outline

- Longevity of electromagnetic actuators at high pressure, temperature and cycle time
- Low-cost consumables
- Tube expansion as a model system
- Some practical applications

tube expansion
the technique

- What happens when a high current is passed through a thin conductor?

![Basic vaporizing bridge-wire circuit](image)

W- wire/foil
C- Capacitor 480 µF
L- Circuit Inductance
S- Switch
R- Circuit Resistance 10 mΩ
V- Voltage 2000-8600 V
procedure for tube expansion

Annealed copper alloy 122 tubes expanded by the pressure created by rapid vaporization of metallic wire aligned with the axis of the tube

Pressure transferred from the point of vaporization to the inner wall of the tubes by an incompressible medium (80 grade urethane)
measurements

• Velocity: 2 channel periscopic PDV focused at laterally located points on the outer wall of the tube.

• Current and Voltage: Rogowski coil and 1000 to 1 Voltage probe respectively.
tube expansion results: aluminum wire

- 9.6 kJ energy level
- 6.7 kV voltage level
- Φ1.524 mm (0.06")
- ID 25.4 mm (1"")
- annealed copper tube

Net Δr:
- PDV: 8.3 mm
- Calliper Measurement: 7.6 mm
Conclusions from tube expansion experiments

• Aluminum is better vaporizing material

• Faster capacitor bank gives higher efficiency

• Velocity rise time is 1-2 µs

Capacitor bank 1: current rise time: 18-20 µs
Capacitor Bank 2: current rise time: 28-30 µs
Urethane pad assisted forming
Schematic for impact forming using vaporizing foils. Aluminum foil insulated from fixture and flyer plate

Experimental set up
Results of perforated steel sheet experiments

0.55 mm thick, AA 3003, H14 formed by vaporizing 0.013 mm thick aluminum foil with input energy of 5.6 kJ

0.55 mm thick, AA 3003, H14 formed by vaporizing 0.013 mm thick aluminum foil with input energy of 6.4 kJ
formability studies

• 0.05” thick Grade 2 CP Titanium sheets were formed into a channel die with a sinusoidal cross section
• Full conformance with the die results in 22% strain
• Tensile test results in failure at ~18% strain
• Polyurethane was used as a pressure transfer medium
• Forming was done in a quasistatic hydraulic press and by using vaporizing foils at different input energies.
results: titanium forming

Notice shearing decreases as power increases
results: aluminum forming

• 0.381 mm thick AA 3003 H19
• quasistatic tensile elongation limit: 7%
• formed into a die with strain at full conformity= 22%
Instrumentation
Current and Voltage histories for input energy of 6.4 kJ into a 0.005" thick aluminum foil
velocity
other variants and applications
Radial expansion of a urethane rod by passing rapidly vaporizing an aluminum wire surrounded by an oxidizer fuel mixture.
Forming, embossing

0.5 mm thick grade 2 CP titanium formed into a cellphone case die using vaporization of a 0.127 mm thick aluminum foil with input energy of 5.6 kJ
shearing

- 0.7 mm thick spring steel sheets sheared
2 aluminum plates welded at 4 kj input energy

3 aluminum plates welded at 4.8 kj input energy

4 aluminum plates welded at 4.8 kj input energy

AA6061 T6 welded with AZ91D (mag alloy)
rapid metal vaporization: an exciting impulse metalworking technique
Conclusions

- Formability increases with forming speed
- Rapidly vaporizing metallic foil, strips and wires is a robust method for high velocity metalworking
- The cost for consumables is very less
- Low to no standoff required
- Same basic equipment can be used for forming, shearing, welding etc
- Industrial adaptation possible
Question?

• vivek.4@osu.edu