An Investigation of Magnetic Pulse Welding to join dissimilar metals

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Background

- Welding of dissimilar metals is highly desired for automotive, aerospace, and other applications.
- Fusion welding cannot be used in such applications due to differences in melting temperatures, intermetallic phase stresses generated, and potential cracking.
- Magnetic Pulse Welding (MPW) uses a capacitor bank charged with tens to hundreds of kJ and then quickly dissipated into an electromagnetic coil.
- Eddy currents in the workpiece are created which repel the conductive material away from the coil at a high velocity, on the order of tens to hundreds m/s.
- The significant impact energy creates a solid state weld if the flier workpiece collides with a stationary one.

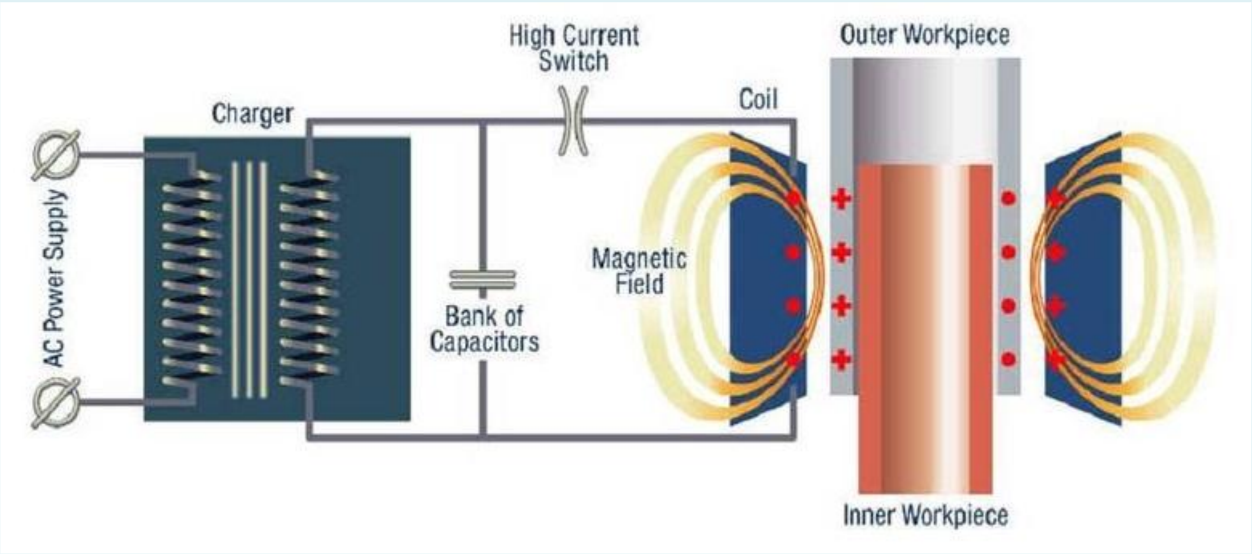

Figure 1. Schematic of MPW [1].

Figure 2. Example of MPW components from a) Ford 4" drive shaft, b) Boeing 777 torque tube and c) Xerox machine rollers [2]

Shaft and tube experiments

- A MPW weld was achieved by placing a shaft into a tube with a gap between the two into a circular coil and applying a current (cut specimen shown in Figure 3).
- The weld interface between the two materials is characterized by a wavy interface as shown in Figure 4.

Figure 3. Welded specimen cut to show weld [3].

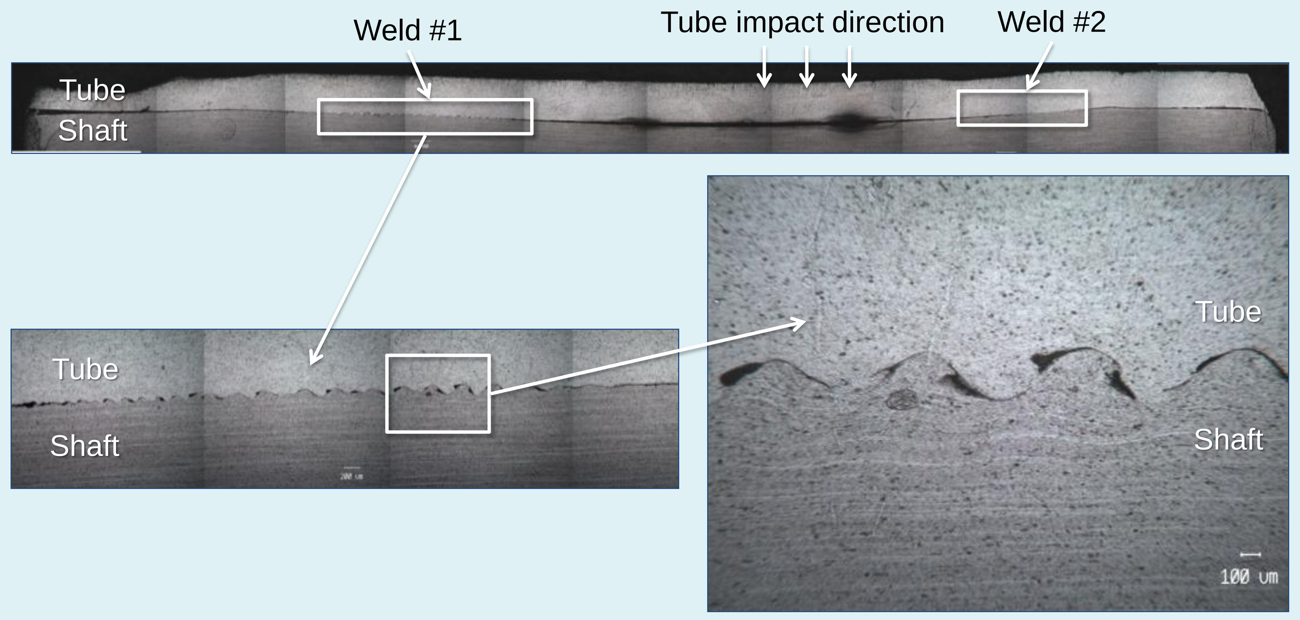

Figure 4. Al-Al wavy interface at 50x, 100x, and 200x magnification [3].

- Varied gap spacing from 1mm to 2.5 mm and power level from 30% to 90% to observe respective effects.

Abstract

- Magnetic Pulse Welding (MPW) is the process of accelerating a flier workpiece into a stationary workpiece to create a solid state weld.
- Velocity of the flier workpiece must be above 200 m/s to achieve a weld.
- Achieving a weld depends on:
  - Material choice
  - Angle of impact
  - Coil geometry
  - Stand-off gap between the two workpieces
  - Power supplied to the coil
- Using a uniform pressure coil and axisymmetric coil, the effects of stand-off gap, workpiece thickness, and power supplied to the coil were initially investigated.
- An alternative E-shaped coil was designed, analysed, fabricated, and tested.

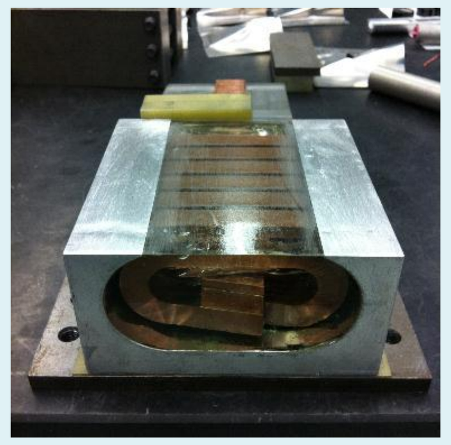

Figure 5. Uniform pressure coil

Figure 6. Axisymmetric coil

Place Holder

E-shaped coil design and Experiments

- The coil developed was based on a design previously tested extensively by Aizawa et. al [4].
- Key parameters considered in the design process:
  - Minimum cross-section of the coil
  - Magnetic repulsion force
  - Cost

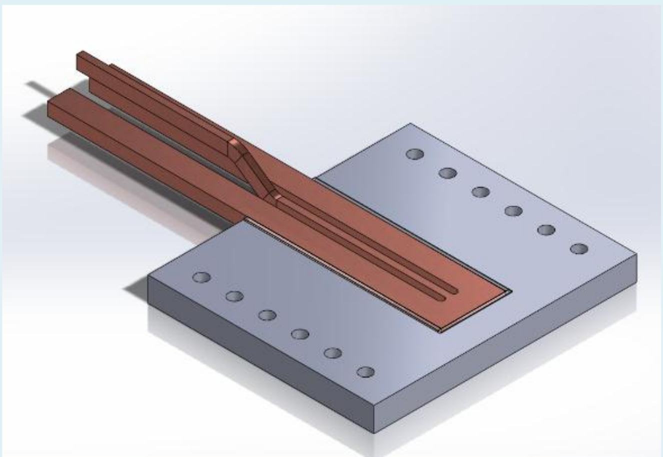

Figure 7: CAD model of the E-shaped coil

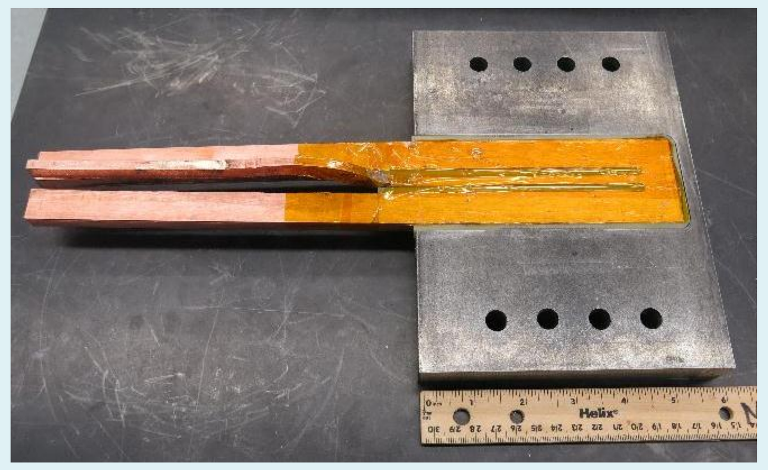

Figure 8: E-shaped coil made from CAD model

Measuring Velocity of Workpiece

- Photon Doppler Velocimetry (PDV) uses a laser directed at the flier plate to obtain the velocity measurement by observing the Doppler shift in the reflected beam from the flier plate.
- The data from the PDV is then converted from a frequency domain to velocity using the short Fourier transform in Matlab.
- This allows comparison of velocity from the current setup.

$$f_{beat} = \frac{v}{\frac{\lambda}{2}}$$

f_{beat} = Beat Frequency
v = Target Velocity
λ = Laser Wavelength

Results

- Welding was achieved with shaft and tube welding using a sacrificial coil.
- The E-shaped coil proved to create significant deformation effects on the workpiece.
- More experimentation with the E-shaped coil is needed.

Figure 9 : Deformation in Aluminum plate caused by E-shaped coil. Sample was run at 90% power.

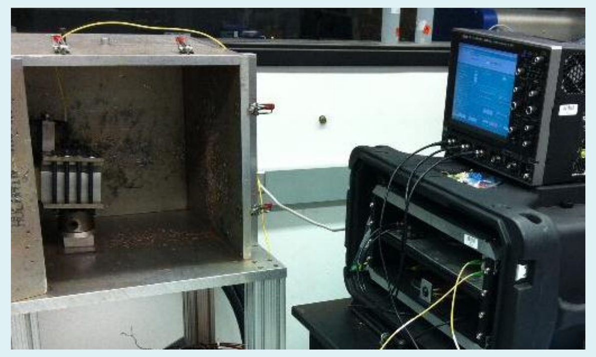

Figure 10: Experimental Setup with forming box, PDV probe and oscilloscope.

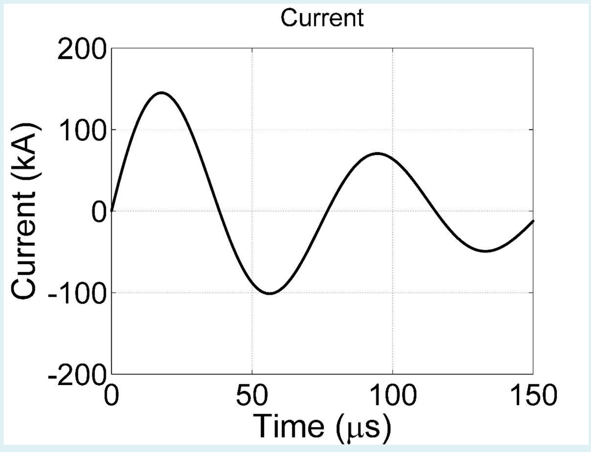

Figure 11: Discharge current over time

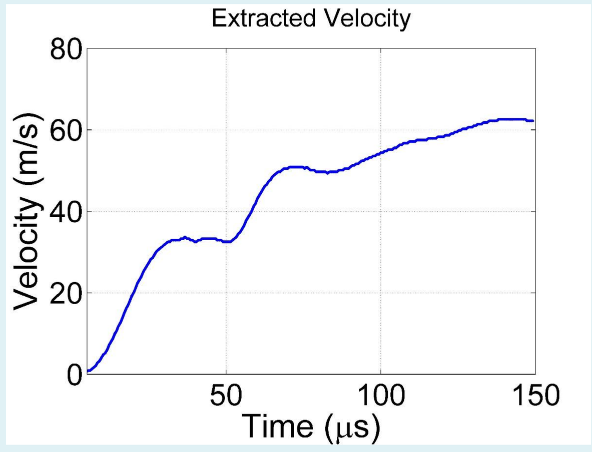

Figure 12: Velocity of the flier plate as accelerated by the uniform pressure coil

Conclusions

- Using a sacrificial coil, successful shaft and tube welding was achieved.
- Extensive testing with the E-shaped coil is still needed.
- The effects of impact angle, power level, and stand-off gap need investigation with the current setup at UNH.

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- Dr. Brad Kinsey
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- Scott Campbell

Additional Information

Additional information, reference papers, and various technical documents written over the course of this project can be found by scanning the QR code to the right, along with a more in-depth, standalone version of this poster.

Refrences

[1] Blakely, M. (2008) "Filler Metal is for Wimps", Fabricating and Metalworking, April.
[2] Magneform, *www.magneform.com,* 2014.
[3] Ethan Thibaudeau, "Development of analytical and experimental tools for magnetic pulse welding", Master's degree thesis, University of New Hampshire.
[4] T. Aizawa, M. Kashani, and K. Okagawa, "Application of Magnetic Pulse Welding for Aluminum Alloys and SPCC Steel Sheet Joints", *Welding Research, Vol. 86,* May 2007.