Modelling Pulse Magnetic Welding Processes – an Empirical Approach

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The Process

1. Due to magnetical pressure, the tube is accelerated to the center
2. High pressures at the collision point are developing
   - A material jet is created at the collision point.
3. Material within the contact zone changes to a highly viscous state
   - Formation of a wavy interface
Experiments

<table>
<thead>
<tr>
<th>Properties EN AL6063</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Resistance</td>
<td>$3.3 \times 10^{-8} , \Omega , m$</td>
</tr>
<tr>
<td>thermal conductivity</td>
<td>$201 , W , m^{-1}K^{-1}$</td>
</tr>
<tr>
<td>specific heat capacity</td>
<td>$898 , J , kg^{-1}K^{-1}$</td>
</tr>
<tr>
<td>thermal expansion coefficient</td>
<td>$23.5 \times 10^{-6} , K^{-1}$</td>
</tr>
<tr>
<td>permeability $\mu$</td>
<td>$1 , \mu_0 = 1.2566 \times 10^{-6} , H , m^{-1}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>240 $\mu$F</td>
</tr>
<tr>
<td>Inductivity</td>
<td>1,966 $\mu$H</td>
</tr>
<tr>
<td>Charging Energy</td>
<td>7, 8 and 9kJ</td>
</tr>
<tr>
<td>Frequency</td>
<td>7.3 kHz</td>
</tr>
<tr>
<td>skindepth</td>
<td>1.07 mm</td>
</tr>
</tbody>
</table>
Simulations – Sequential Coupling of Electrodynamiс and Mechanical FEA

\[ p_{\text{Mag}}(x,t) \]

\[ \varepsilon(x,t) \]

grid deformation

time loop
Simulations – Empirical Model

Possible influences to weldability:

- $\alpha$ inclination-angle,
- $v_\perp$ collision point velocity,
- $V_{cp}$ collision point velocity,
- $P_{PL}$ plastic work,
- $\varepsilon$ deformation.

$$B = f(\alpha, v_\perp, v_{cp}, P_{PL}, \varepsilon)$$

bondage

no bondage
Simulations – Influence of the Temperature
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Simulations – Sequential Coupling of Electrodynamical and Mechanical FEA

\[ p_{\text{Mag}}(x,t) \]

ANSYS Electromagnetic Simulation → ANSYS Mechanical Simulation → ANSYS Thermal Simulation

grid deformation

time loop
Model Setup

Plastic deformation bolt collision time + ∆t
Plastic deformation tube collision time + ∆t
Welded in experiment

Energy: 7kJ
Model Setup

Energy: 9kJ

![Graph showing deformation and welded in experiment with energy labeled as 9kJ]
Model Setup

Velocity [m/s]

Energy: 9kJ

welded in experiment

V⊥ four steps before collision
Results

Currency distribution of the electromagnetical simulation and measurement
Results

Currency distribution of the electromagnetical simulation and measurement
Modelling Pulse Magnetic Welding Processes – an Empirical Approach

Results

- Plastic deformation tube collision time
- Welding limit collision velocity
- Welded in experiment
- Collision velocity four timesteps before collision
- Welding limit Plastic deformation
- Welded in simulation

Energy: 8kJ
Conclusions

- The used FEA – Model was a complete sequential-coupled thermal-electromagnetical-mechanical Simulation.

- Simulations show, that the heat generation due to plastic deformation does not account for the welding process.

- Set up and calibration of a bonding-model for accurate material bonding at the welding-interface

- Reduction of the set of necessary parameters, leaving the normal collision velocity and plastic deformation.
Outlook

• Further validation is necessary in order to expand the extent of validity as well as the use for additional Materials.

• An open question is the welding behaviour with mixed materials.

• The implicit FEA - software was not designed to calculate big deformations
  → Making use of explicit FEA – software such as AUTODYN

• Loosening and cracking were not part of the model as well.
Thank you!

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