Joining as an Enabling Technology for Mainstream Vehicle Lightweighting

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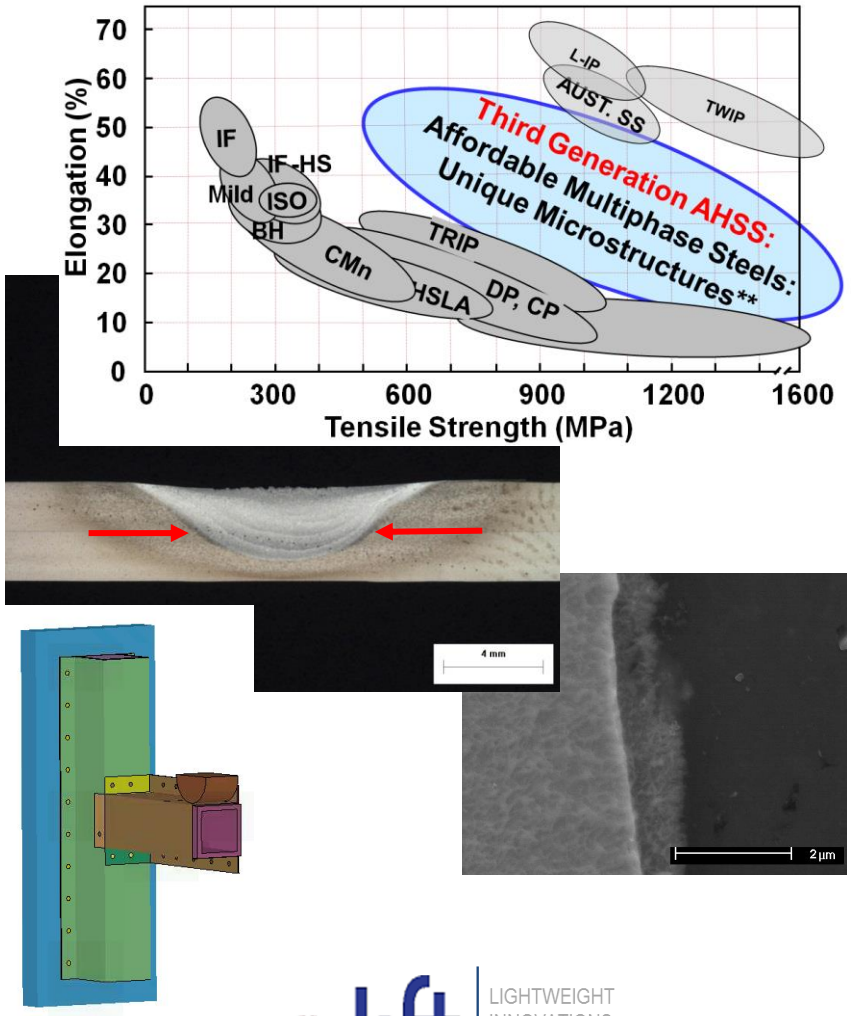
LIGHTWEIGHT INNOVATIONS FOR TOMORROW

Operated by: ALMMII

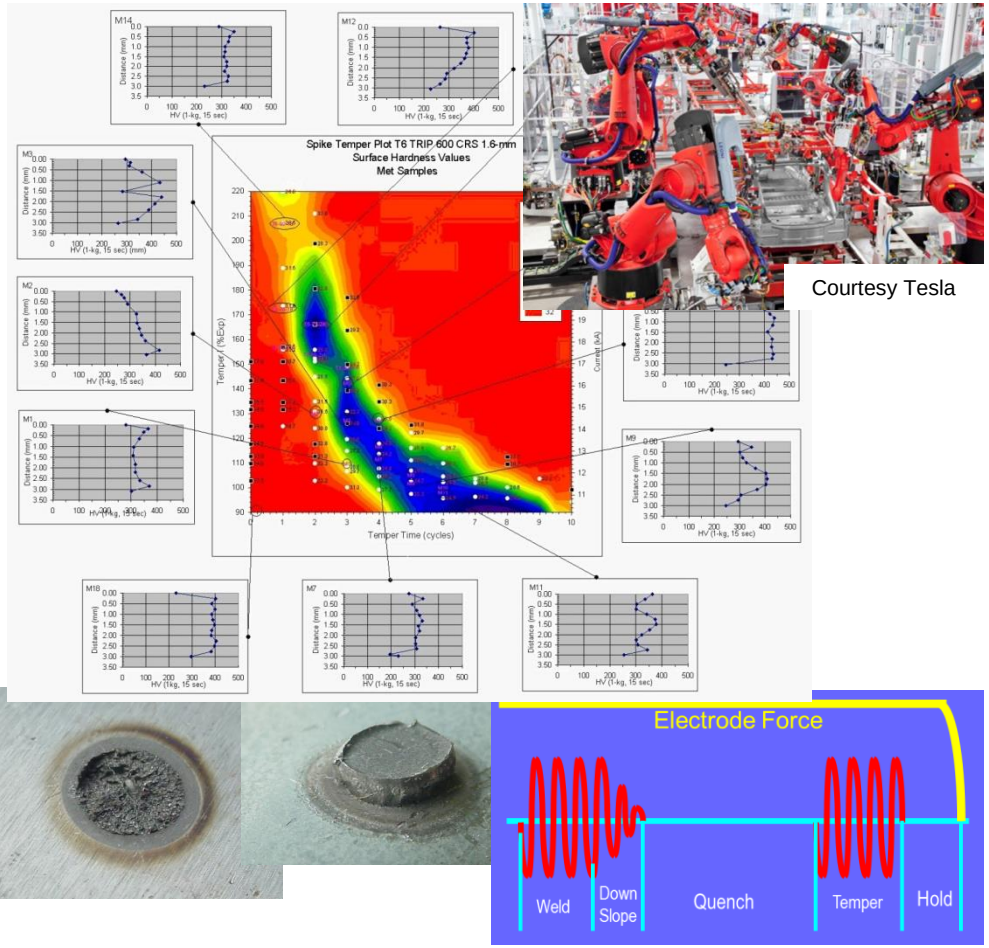
Materials for Vehicle Body-in White Lightweighting

- **Newer generation steels**
  - Advanced high strength steels
  - Generation III steels
- **Aluminum alloys**
  - Sheet grades (5XXX, 6XXX, 7XXX)
  - Alternate product forms
    - Castings
    - Extrusions
- **Dissimilar metals joining**
  - Aluminum to steel combinations
  - Aluminum to magnesium
  - Metallurgical interactions
  - Material properties considerations
- **Joint performance guidelines**



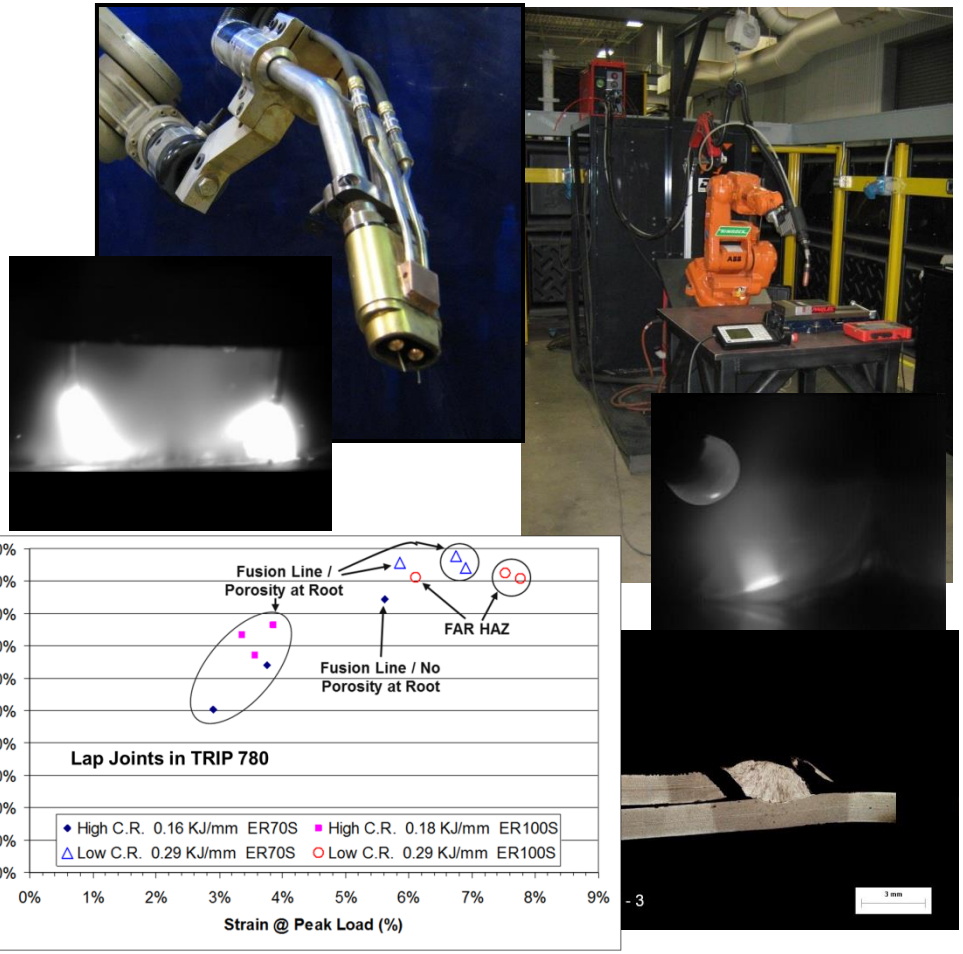
Welding of Advanced High Strength and Generation III Steels

- **Implicit toughness of AHSS and Gen III spot welds**
  - High hardenability
  - Rapid thermal cycles of spot welding
  - Eutectic forming additions
  - Interfacial failures on destructive testing
- **Use of in-situ tempering techniques**
  - Fully hardened weld zones
  - Cooling ~1-sec
  - Short time tempering to provide toughness
  - Improvements in failure modes
  - Implications for crash performance



Welding of Advanced High Strength and Generation III Steels – cont.

- **Advanced gas metal arc welding processes**
  - Reciprocating wire feed
  - Tandem processing
  - Flux core welding
  - Hybrid laser welding
- **Application to advanced high strength steels**
  - Heat affected zone softening
  - Reduced joint efficiencies
  - Fatigue performance
  - Stamping induced strain
- **Improvements in GMAW methods**
  - Cooling rate enhancement
  - Productivity (speed)
  - Filler metal development



Joining Methods for Aluminum Sheet – Resistance Spot Welding

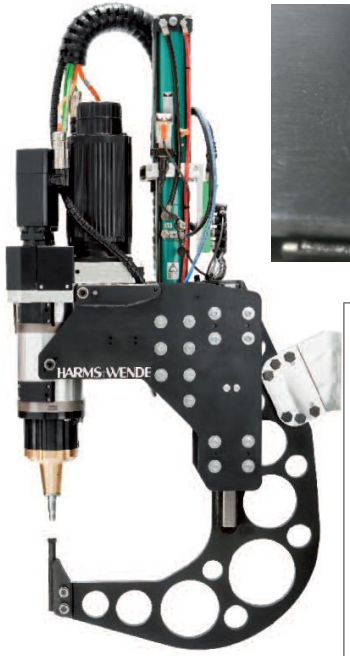
- **Challenges with electrode wear**
  - Weld “drop-outs”
  - Intermittent interfacial failures
- **Additional challenges with newer power supplies**
  - MFDC vs AC
  - Accelerated electrode wear
- **Improved weld morphology through enhanced surface heating**
  - Profiled electrodes with dressers
  - Third body “strips”
- **Improvements in weld quality**
  - Enhancements in joint reliability
  - Frequent maintenance of electrode systems

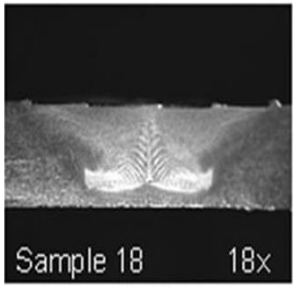
Courtesy General Motors

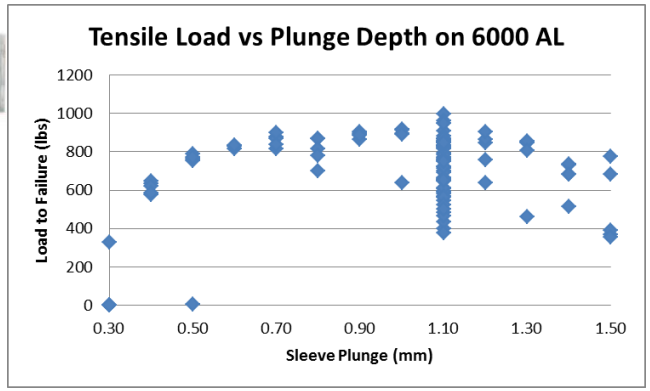
Courtesy Fronius

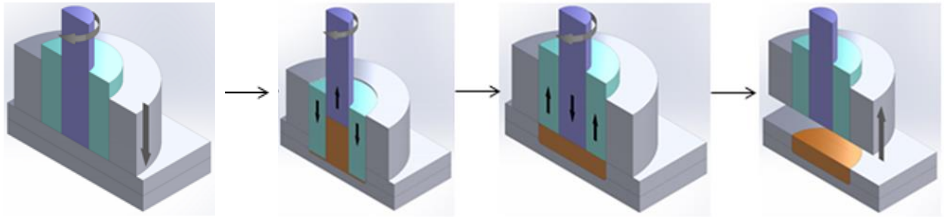
Joining Methods for Aluminum Sheet – Refill Friction Stir Spot Welding

- **Solid-state variants of spot welding**
  - Friction stir spot
  - Swept spot
  - Friction stir stich
  - **Refill friction stir spot**
- **Mechanisms of the process**
  - Shoulder plunge/pin retract
  - Pin advance/shoulder retract
  - Minimal penetration into lower sheet
- **Demonstrated characteristics**
  - Minimal thinning of the top sheet
  - Nominally flush top surfaces
  - Shear strengths equivalent to spot welding



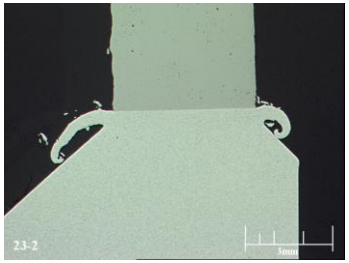


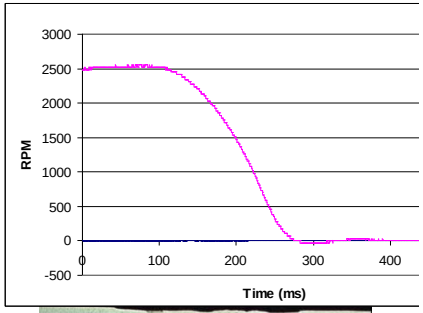


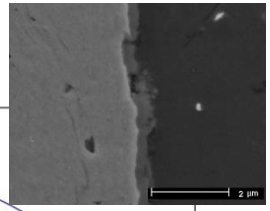


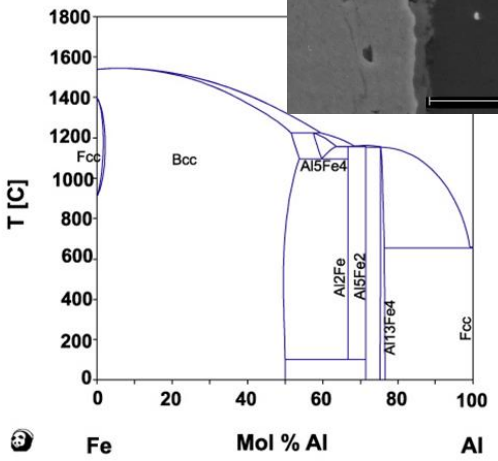
Welding to Aluminum to Steel

- **Process challenged by metallurgical reactions**
  - Melting point suppression
  - Intermetallic formation
- **Friction welding methods**
  - Production technology
  - Driven by short cycle times
  - Kinetic suppression of intermetallics
  - Kinetics aluminum alloy dependent
- **Adaptation to other process technologies**
  - Resistance spot welding variants
    - Direct welding
    - Roll bonded transition materials
    - Braze assisted
  - Solid-state process variants
    - Matching thermal cycles demonstrated in friction welding



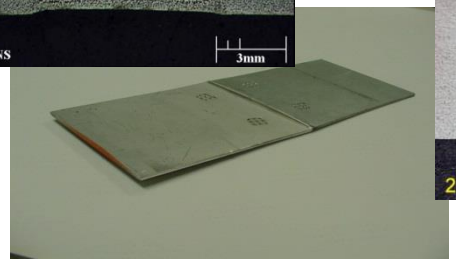


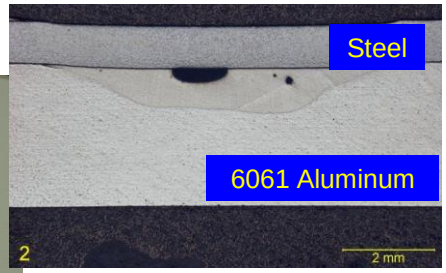




Calculated Fe-Al phase diagram assessed by 1991Sei

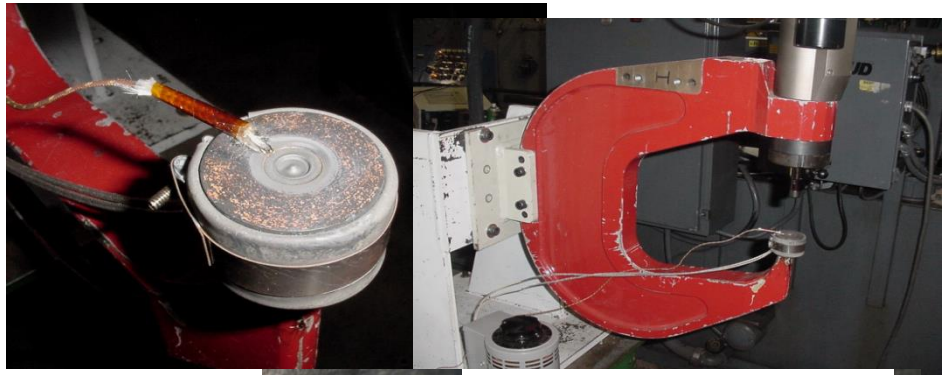
NIMS





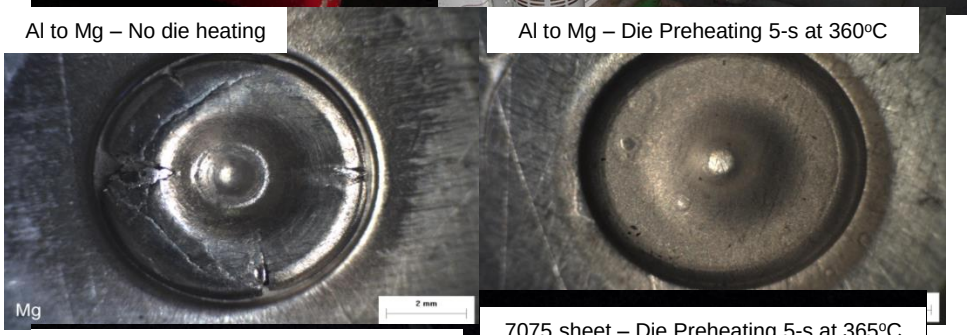
Thermally Assisted Mechanical Fastening

- **Mechanical fastening widely considered for dissimilar material joints**
- **Challenges for low ductility materials**
  - Magnesium alloys (3% - 10% elongation)
  - Aluminum castings (3% elongation)
  - 7XXX alloys
  - Cracking on forming during fastening
- **Warm fastening to enable formability**
- **Application of a heated die**
- **Contact conduction for local metal heating**
- **Demonstrated for both magnesium and high strength aluminum sheet**



Al to Mg – No die heating

Al to Mg – Die Preheating 5-s at 360ºC

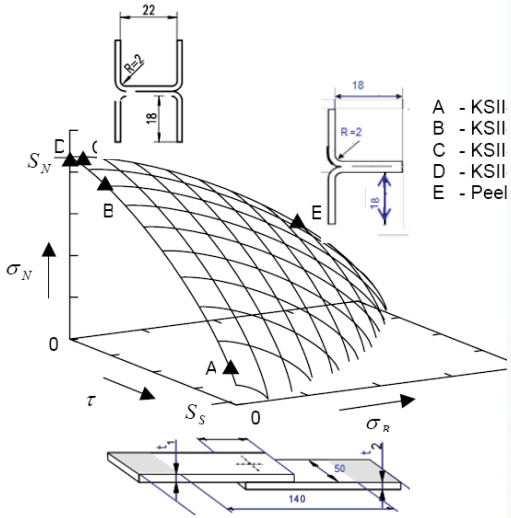


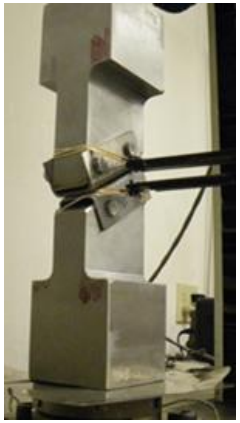
Al to Mg – Die Preheating 2-s at 360ºC

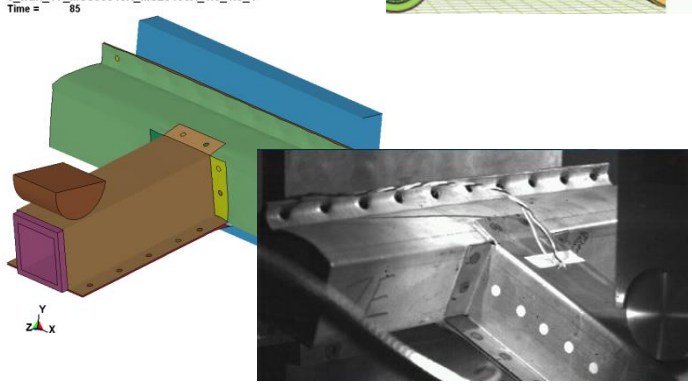
7075 sheet – Die Preheating 5-s at 365ºC

Performance Prediction of Assembled Structures

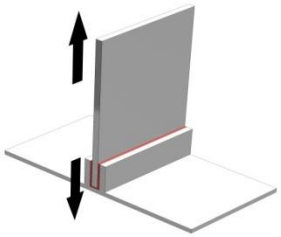
- **Efforts to minimize physical crash testing**
- **Shell based modeling for crash prediction**
- **Spot welds in mild steels considered rigid lengths**
- **Challenged by advanced materials and joining processes**
  - Non-button failure modes
  - Joint separation before extensive plasticity of the base metals
- **Empirical methods for establishing joint failure criterion**
  - Combined loading based criteria
  - Independent empirical testing to define all constants in the criterion
  - Closed form or look-up table for individual joint criteria
- **Component testing for validation**
- **Full crash validation**



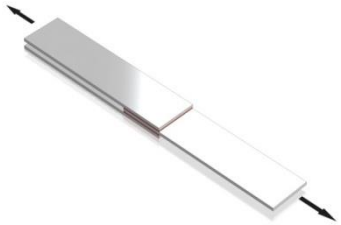




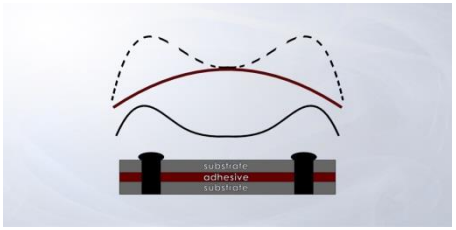
Adhesives in Lightweighting



Pi-joint:
Any material combination

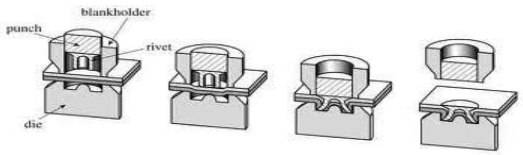


Double lap shear:
Any material combination



Weldbonding or rivetbonding:
Increase peel performance at stress concentrations

- **Distribute stress over a larger joining surface area**
- **Enable non-weldable dissimilar materials joining**
- **Enhance galvanic corrosion protection**
- **Enable weldbonding and rivetbonding:**
  - increases joint efficiency, fatigue performance, NVH.
  - Resistance, projection, FSSW, laser, ultrasonic weldbonding



Joining as an Enabling Technology for Mainstream Vehicle Lightweighting - Summary

- **New technology trends for automotive BIW components**
  - Advanced high strength and Generation III steels
  - Newer aluminum alloys and product forms
  - Dissimilar materials product forms
  - Assessment tools for advanced product performance
- **Joining of advanced high strength and Gen III steels**
  - Spot welding with in-situ tempering
  - Advanced gas metal arc techniques
- **Welding of aluminum sheet**
  - Advances in resistance spot welding
  - Friction stir spot welding methods
- **Dissimilar materials joining**
  - Welding aluminum to steel
  - Thermally assisted mechanical fastening
- **Performance prediction of welded structures**
  - Reduction in required crash testing
  - Shell models for structural analysis
  - Empirical failure criteria for specific joints
  - Adaptable to a range of materials and joining methods
- **Use of adhesives**
  - Joint designs for bonding
  - Hybrid joining with welds or fasteners

Questions?

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LIFT: Technology Pillar Leader, Joining and Assembly

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