Room-temperature Stamping of High-Strength Aluminum Alloys

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Project ID # mat126

Overview

Timeline

- Start: 10/2016 (FY17)
- Finish: 09/2019 (FY19)
- % complete (time): ~50%
- % spent (budget): ~24%

Barriers

- Strength: Develop process for stamping high-strength Al for structural applications without degrading its high strength
- Formability: Develop ways to enable sufficient formability of Al to stamp it at room-temperature

Budget

- Total project funding
  - DOE: $ 1M
  - Industry cost share: 30%
- Funding since inception: ~$ 540K
- Future funds anticipated: ~$ 460K

Partners

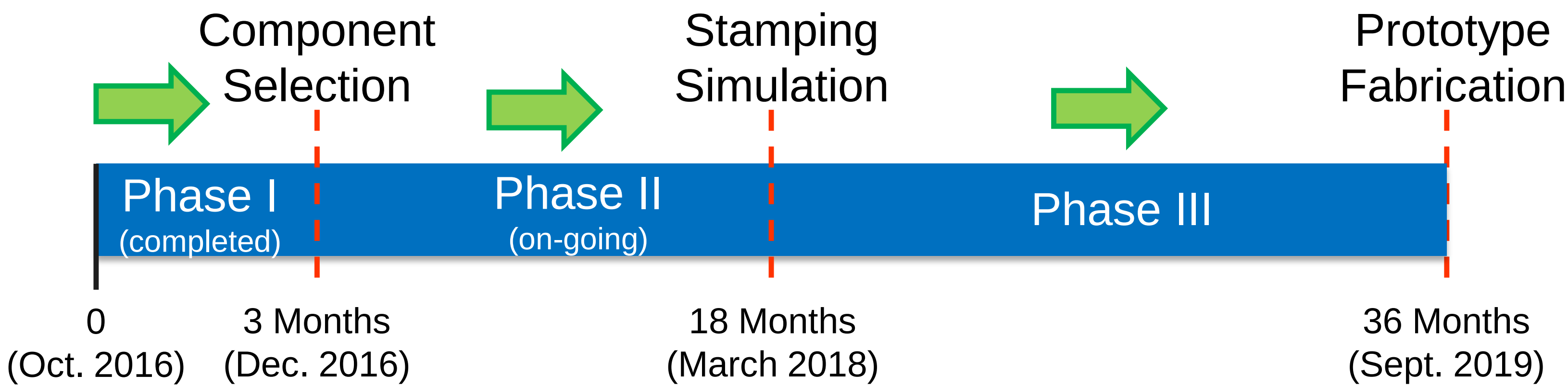
- Magna-Stronach Centre for Innovation (Tier-1)
- General Motors (OEM)

Relevance/Objective

- DOE-VTO
  - Long-term objective → 50% mass reduction of a vehicle
  - 2025 Target → 25% glider mass reduction, relative to comparable 2012 vehicles, at an added cost of no more than $5/lb weight saved
- USDRIVE
  - Aluminum components offer potential overall weight reduction of 40-60% when replacing cast iron/steel
  - Methods to improve the formability of high-strength Al alloys (>600 MPa), to values equivalent to steel, are a high priority research need
- Project objective
  - Develop thermo-mechanical approaches to enable room-temperature stamping of high-strength (7xxx) Al alloys
- Challenges
  - High-strength Al alloys do not have sufficient formability to be stamped at room-temperature
  - Warm/hot stamping is costly and may require post-forming heat-treatments to regain the high-strength

Approach

Develop thermo-mechanical processing to enable cost-effective stamping of high-strength Al at room-temperature and without the need for additional heat-treatment



- Identify a component benefitting from being made of high-strength Al alloys
- Perform experiments to evaluate thermo-mechanical treatments
- Use constitutive relations and stamping simulations to verify that the selected component can be stamped at room-temperature
- Integrate microstructure and mechanical property models
- Fabricate and characterize the stamped component

Approach

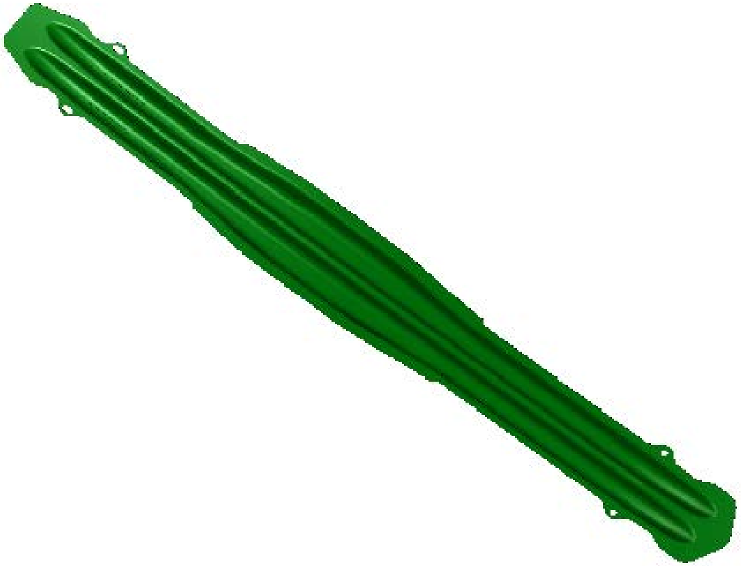
- Phase I (3 months)
  - Task 1: Identify 3-5 potential stamped sheet components
  - Gate 1: Demonstrate potential for sufficient return on (DOE) investment and the potential for commercialization to replace high-strength steel with high-strength Al

- Phase II (15 months)
  - Task 2: Determine strengthening potential of W temper formed 7xxx Al alloys
  - Task 3: Determine constitutive relations for selected Al alloys
  - Task 4: Perform stamping simulation for the selected prototype structural component
  - Gate 2: Stamping simulations that predict with confidence that the selected component can be stamped in at least one 7xxx Al alloy-temper combination at room-temperature

- Phase III (18 months)
  - Task 5: Integrate microstructure and mechanical property models for the selected Al alloys
  - Task 6: Fabricate prototype component
  - Task 7: Characterization of prototype component

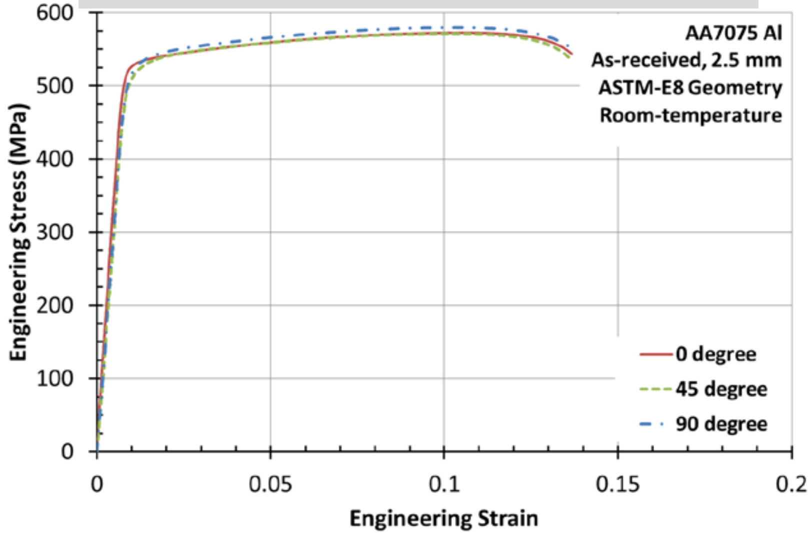
Accomplishments
Material and Component Selection

- Example of candidate component for high-strength steel substitution by high-strength Al
  - Door side impact beam
  - Rocker outer and inner
  - Roof rail
  - A-pillar inner
- Example of high-strength Al alloys
  - AA7075
  - AA7055
- Estimated weight savings ~30-50%

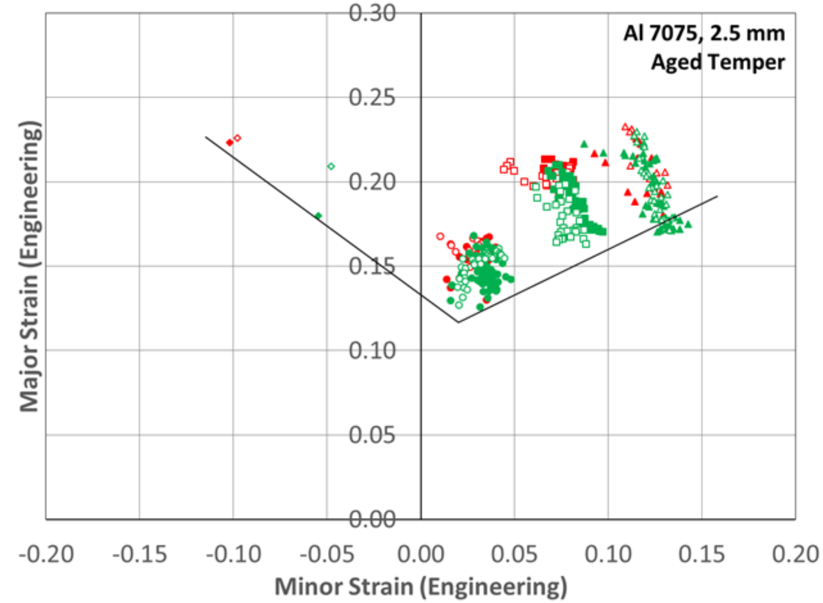


Accomplishments
Material Characterization

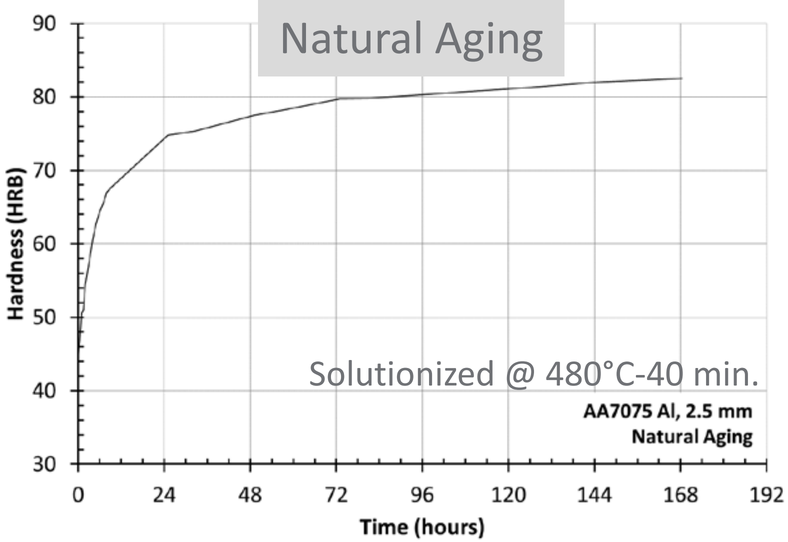
Quasi-static Tension (T6 Temper)



Forming Limit Diagram



Natural Aging



- Initial characterization (mechanical properties) of AA7075 in different tempers via tension testing, hardness and formability testing

Accomplishments
Formability Modeling-Friction Effects

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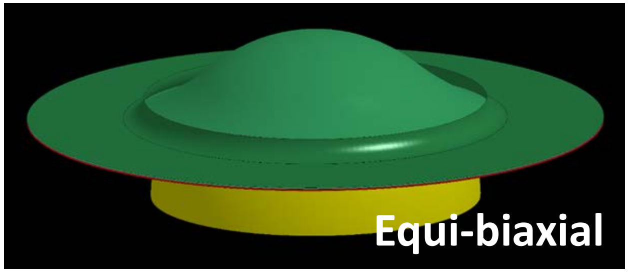

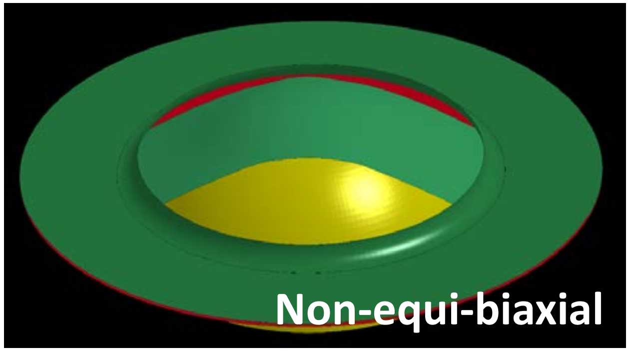

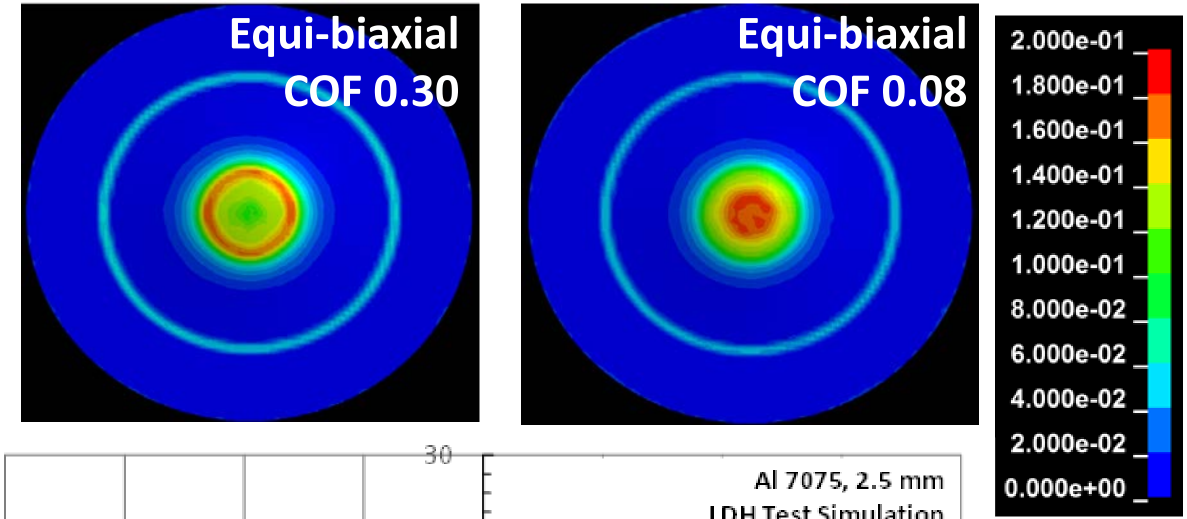

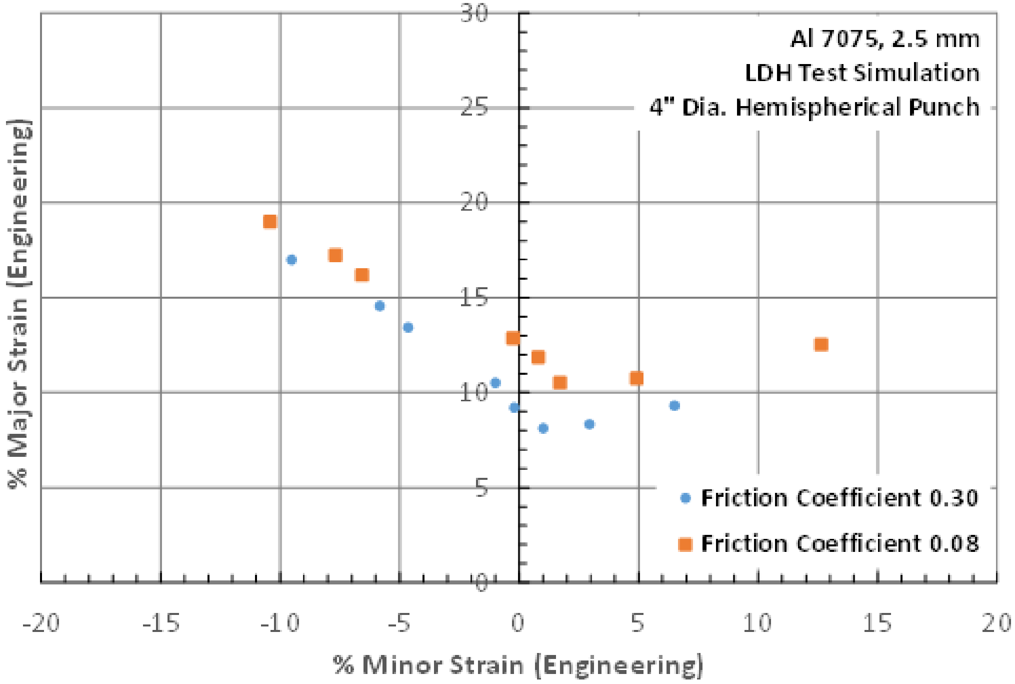

- LS-Dyna; shell elements; and equivalent plastic strain at tensile failure as the limit strain criterion
- “High” coefficient-of-friction lowers the formability

Responses to Previous Years Reviewers' Comments

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- No Reviewers' Comments as this is the first year for project review

Collaboration and Coordination

- Magna-SCFI (Tier-1)
  - Component selection
  - Component model
  - Stamping simulations
  - Prototype fabrication
- General Motors (OEM)
  - Internal studies on lightweighting
  - Component and Al alloy selection
  - Component design
  - Die design
- ORNL
  - Rich Davies – Initial project development

Remaining Challenges and Barriers

- Determine the thermomechanical processing that allows simultaneous formability (at room-temperature) and high strength in the formed component
  - Combined experimental and modeling approach
- High-strength Al can continue to undergo natural aging after forming
  - Post-formed mechanical properties need to be evaluated for long-term thermal stability
- Cost-effectiveness of the proposed approach is unknown

Proposed Future Work

- Develop constitutive relations for selected alloy (PNNL, Magna)
- Perform stamping simulations and iterate on component design (Magna, PNNL)
- Integrate microstructure and mechanical property models (PNNL)
- Design stamping die and stamp prototype component (Magna)
- Characterize the stamped component (PNNL)

Any proposed future work is subject to change based on funding levels

Technology Transfer Activities

- Provide mechanical test data to Magna to develop appropriate material cards for stamping simulations

Summary

- Goal is to develop a process to stamp high-strength Al at room-temperature without a separate precipitation-hardening heat-treatment
- Multiple structural components have been identified that have substantial lightweighting potential if formed out of high-strength Al alloy instead of high-strength steels
- PNNL will develop a thermo-mechanical process and work with OEM and tier-1 supplier to stamp and deliver a prototype component out of high-strength Al

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Technical Backup Slides

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Backup
Example of Prior Literature Reviewed

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8. Kumar, S.D., Amjith, T.R., Anjaneyulu, C., Forming Limit Diagram Generation of Aluminum Alloy AA2014 Using Nakazima Test Simulation Tool, In Procedia Technology, Volume 24, 2016, Pages 386-393.
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