Magnesium-Intensive Front End Sub-Structure Development

Project ID "LM077"

USAMP AMP800

2013 DOE Merit Review Presentation

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AMP800 (DE-EE0006662)

Magnesium-Intensive Front End Sub-Structure Development

Timeline

- Start: June 1, 2012
- End: May 31, 2015
- 20% complete

Budget

- Total project funding
  - DOE: $3,000,000
  - Contractor share: $3,000,000
- Funding received in FY12

  $38,619
- Funding for FY13
  - DOE: $983,650
  - Contractor share: $983,650

Barriers/targets

- *Manufacturability and joining & assembly*: Demonstration of a Mg-intensive multi-material "demo" structure in automotive body applications
- *Predictive modeling & performance*: Performance validation of "demo" structure in crashworthiness, corrosion, fatigue and durability

Partners

- OEMs: Chrysler, Ford, GM
- U.S. Supplier list (slide 5)
- International partners from China and Canada (slide 6)

U.S. Partner Organizations

Industry (15)

ACT Test Panels
AET Integration
Almond Products
Atotech
Cosma Engineering
Forming Simulation Technologies
Henkel
Henrob
Hitachi
Kaiser Aluminum
Luke Engineering
Mag Specialties
North American Die Cast Assn.
PPG Industries
Troy Tooling Technologies

Universities (7)

Lehigh University
Mississippi State University
Missouri Science and Technology
North Dakota State University
The Ohio State University
The University of Alabama
The University of Michigan

International Partner Organizations

Canada

CANMET
(Natural Resources Canada)
Auto 21 Network
University of Waterloo
University of Western Ontario
Ryerson University
University of Sherbrooke
University of Windsor
Centerline Corp.
NRC – Aerospace Divn.
MAGNA
Meridian Lightweight - Canada

China

China Magnesium Center
(Ministry of Science and Technology)
Tsinghua University (Beijing)
Chinalco - Louyang Copper
Zhejiang University
Shanghai Jiao Tong University
Shenyang University of Technology
Xi'an University of Technology
Chongqing University
Northeastern University
Inst. of Metals Research – Shenyang
Shanxi Yingguang Magnesium

Overall Objectives: Relevance

- Design, build and test a Mg-intensive, automotive front-end "demo" structure – leading to lightweight multi-material applications
- Develop enabling technologies in new Mg alloys, joining (including dissimilar metals), corrosion and materials performance (including fatigue and high strain rate deformation) for lightweight automotive structures
- Contribute to integrated computational materials engineering (ICME) efforts specifically focused on magnesium alloy metallurgy and processing
- Collaborate with international and domestic researchers and suppliers to leverage research and to strengthen the supply base in magnesium automotive applications

Approach

- Mass reduction of Mg-intensive body structures: up to 45% less than steel comparator; 20% less than aluminum comparator structure
- Use a "demo" structure to validate key enabling technologies, knowledge base and ICME tools

Project Structure and Timing (MFERD Phase I, II and III)

FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15

MFEDD Phase I. Front End Design and Feasibility

USAMP PROJECT (AMD603) : Magnesium Front End Design & Development (MFEDD)

CANADA-CHINA-USA COLLABORATIVE PROJECT: Magnesium Front End Research & Development (MFERD)

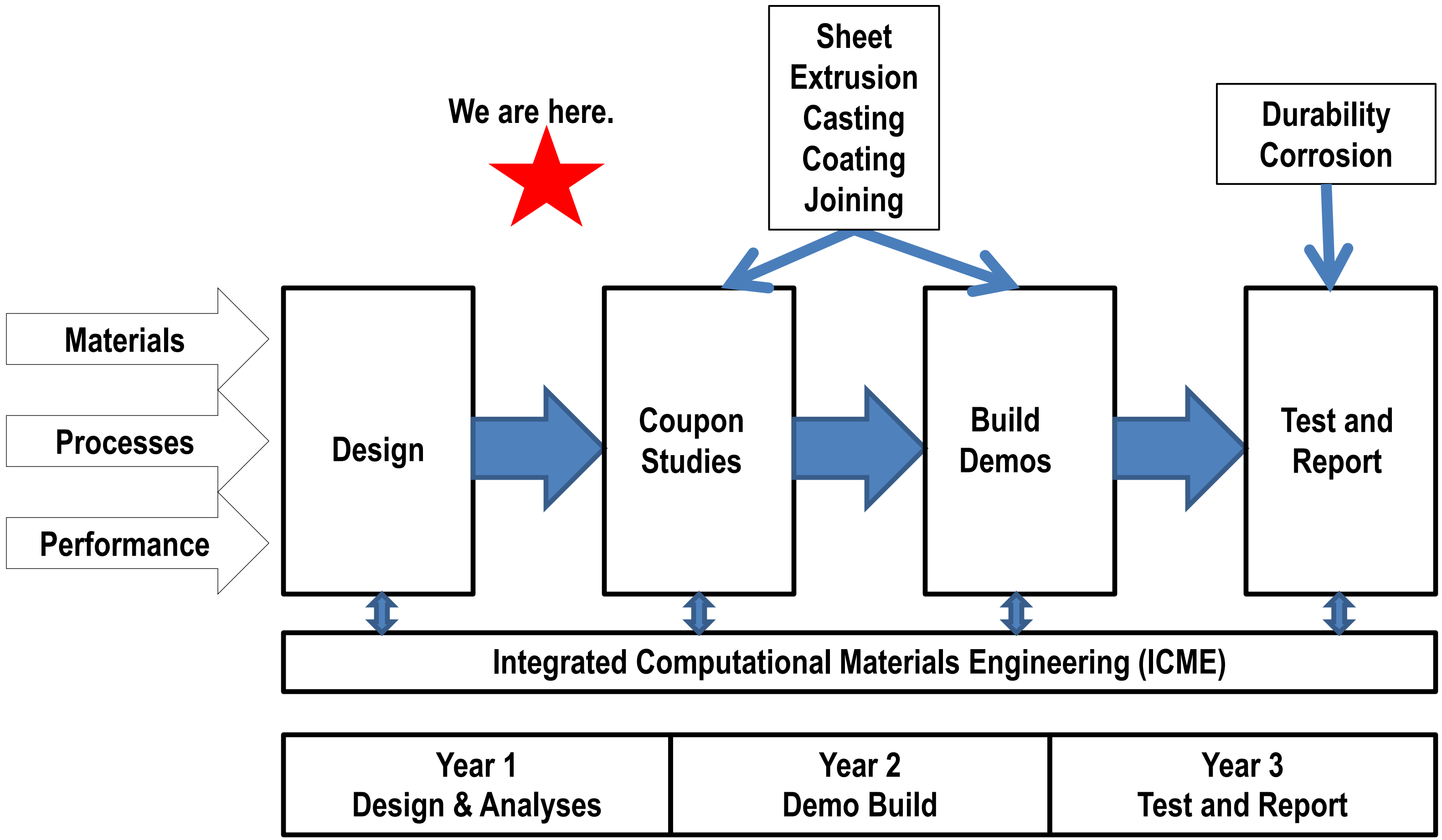
Phase I. Enabling Technology Development (AMD604)
- Crashworthiness research
- NVH research
- Fatigue and durability research
- Corrosion and coatings
- Low-cost extrusion & forming
- Low-cost sheet and forming
- High-integrity body casting
- Welding and joining
- Integrated computational materials engineering

Phase II. Demo Structure (AMD904)

Phase III. Mg-Intensive Front End (AMP800)
- Demo design, build and testing
- Crashworthiness research
- Fatigue and durability research
- Corrosion and coatings
- Extrusion
- Sheet and forming
- High-integrity body casting
- Welding and joining
- Integrated computational materials engineering

Milestones

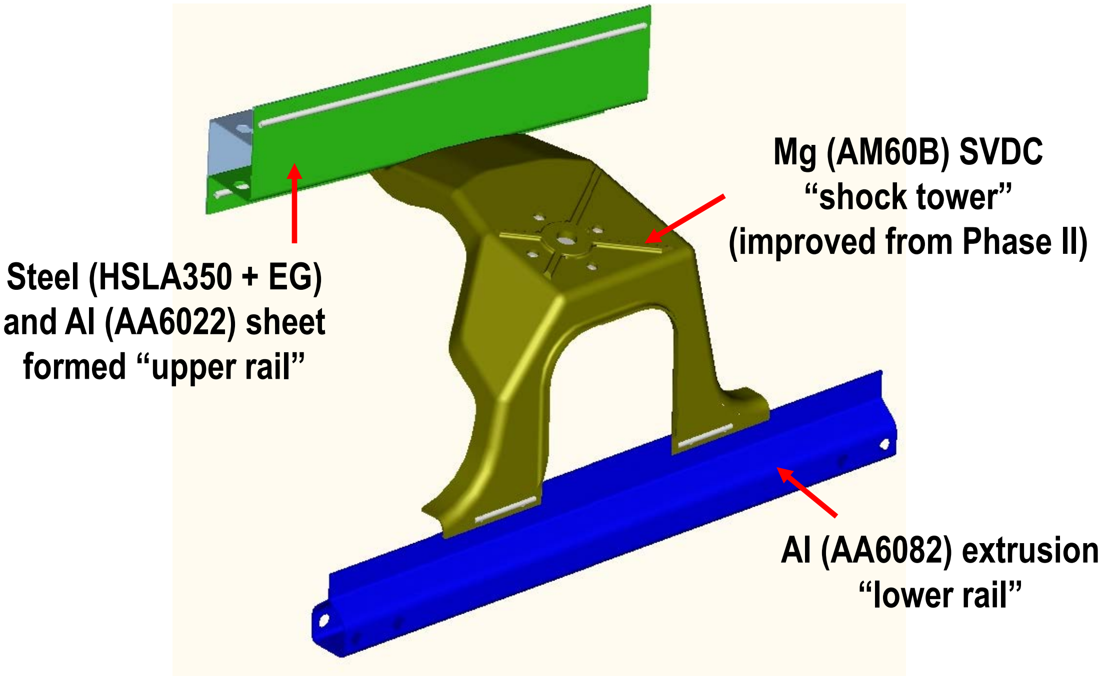
- Project "kick-off" with DOE at USCAR (Southfield, MI) on Sept. 26, 2012
- Design, analyses, part and demo build, test and reports on a "demo" structure



FY2012 Accomplishments - Task 2 Demo Design, Analysis, Build & Testing

- Completed the Mg-intensive multi-material "demo" structure design
  - Mg shock tower (SVDC) with major improvements in casting design
  - High-ductility Al extrusion rail (AA6082)
  - Steel (HSLA350 + EG) and Al alloy (AA6022) sheet rail

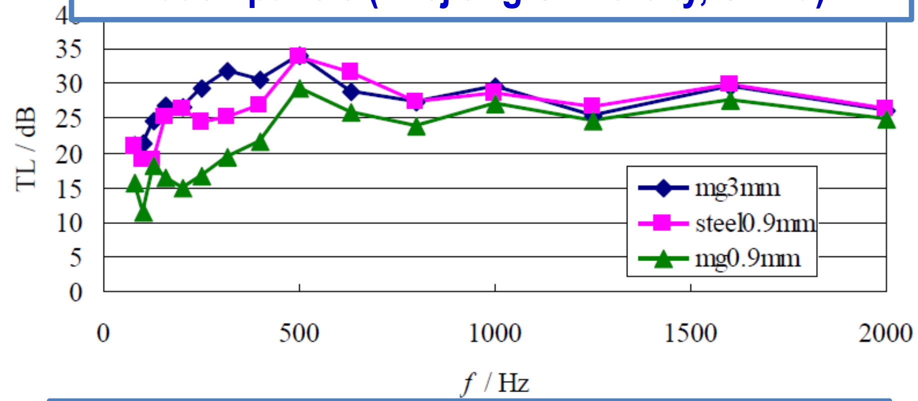
Multi-material "demo" structure design



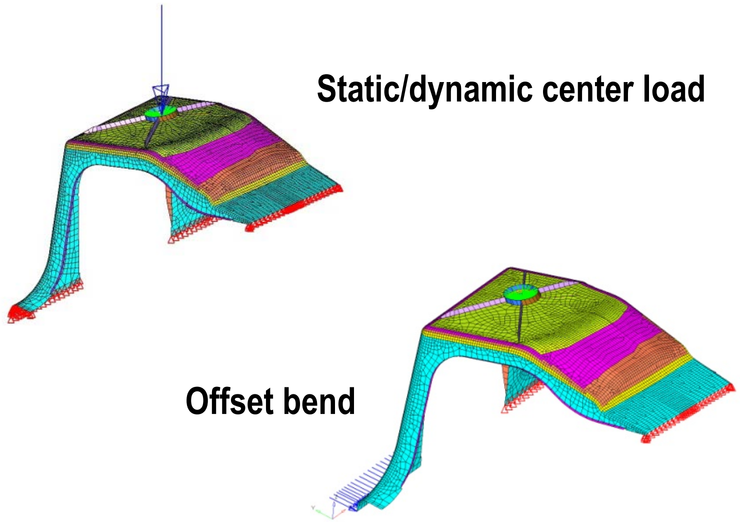
FY2012 Accomplishments - Task 3 Crashworthiness & NVH

- Expanding “shell elements” to “solid elements” material models in LS-DYNA for super-vacuum die casting (SVDC) AM60 alloy: improving crash simulations
- Leveraged NVH testing and simulation results of Mg vs. steel dash panels in China and Canada

Simulation of transmission loss in Mg vs. steel dash panels (Zhejiang University, China)



FEA models for material model evaluation

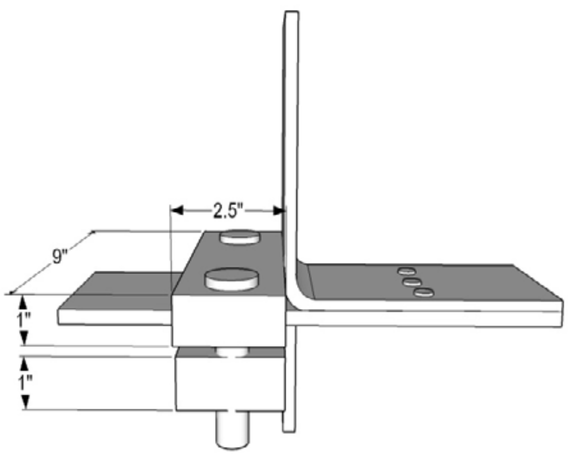


Free-free modal testing of the Viper Mg dash panel (Zhejiang University, China)

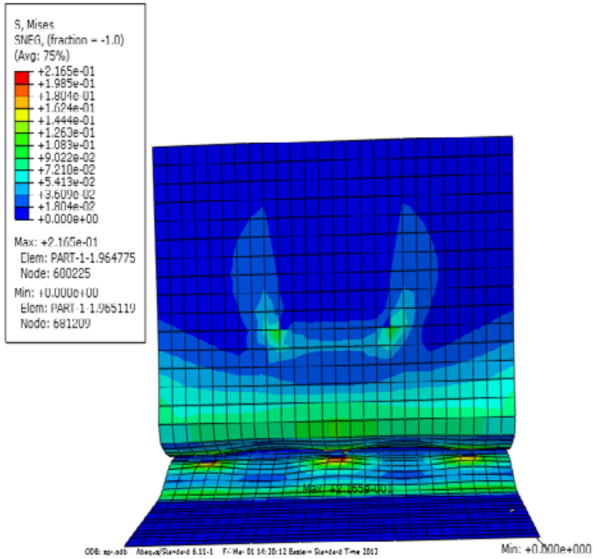
FY2012 Accomplishments - Task 4 Fatigue and Durability

- ❑ Evaluated the discrepancies between the durability simulation and test results in MFERD Phase II and set out plans to improve the predictive models for joint fatigue failure with new measurements
- ❑ Prepared samples to determine the effect of friction-weld pinhole on fatigue

Coach peel style test specimen to validate joint fatigue model



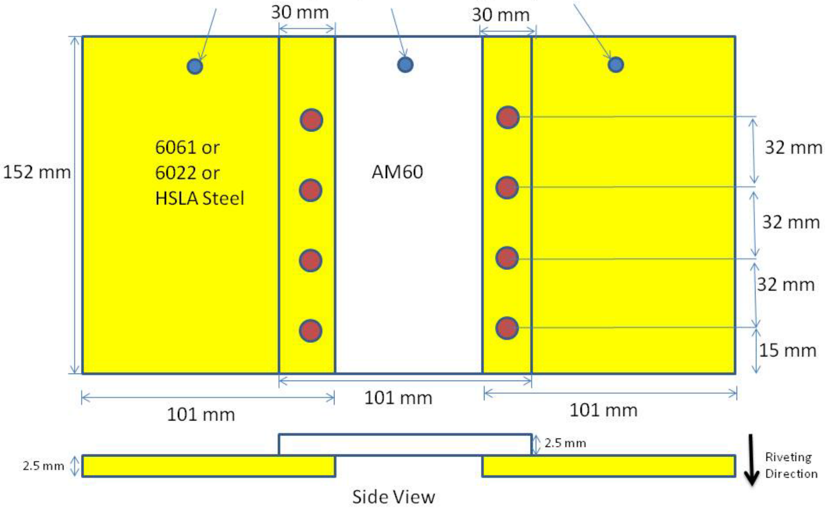
FEA simulation of proposed tests



FY2012 Accomplishments - Task 5 Corrosion and Surface Treatment

- Compiled the 'best practices' on corrosion measurements for Mg structures in automotive applications
- Finalized the plans for galvanic corrosion evaluation of riveted Mg and the influences of Mg surface impurity on corrosion and isolation methods
- Initiated preliminary study on aluminized rivet performance under cyclic corrosion test conditions (Ford cyclic corrosion protocol for test coupons)
- Finalizing details for testing 5 coating strategies for Al-Mg and 3 coating strategies for Al-Mg-Steel coupon assemblies

Multi-material joint for fatigue & corrosion testing

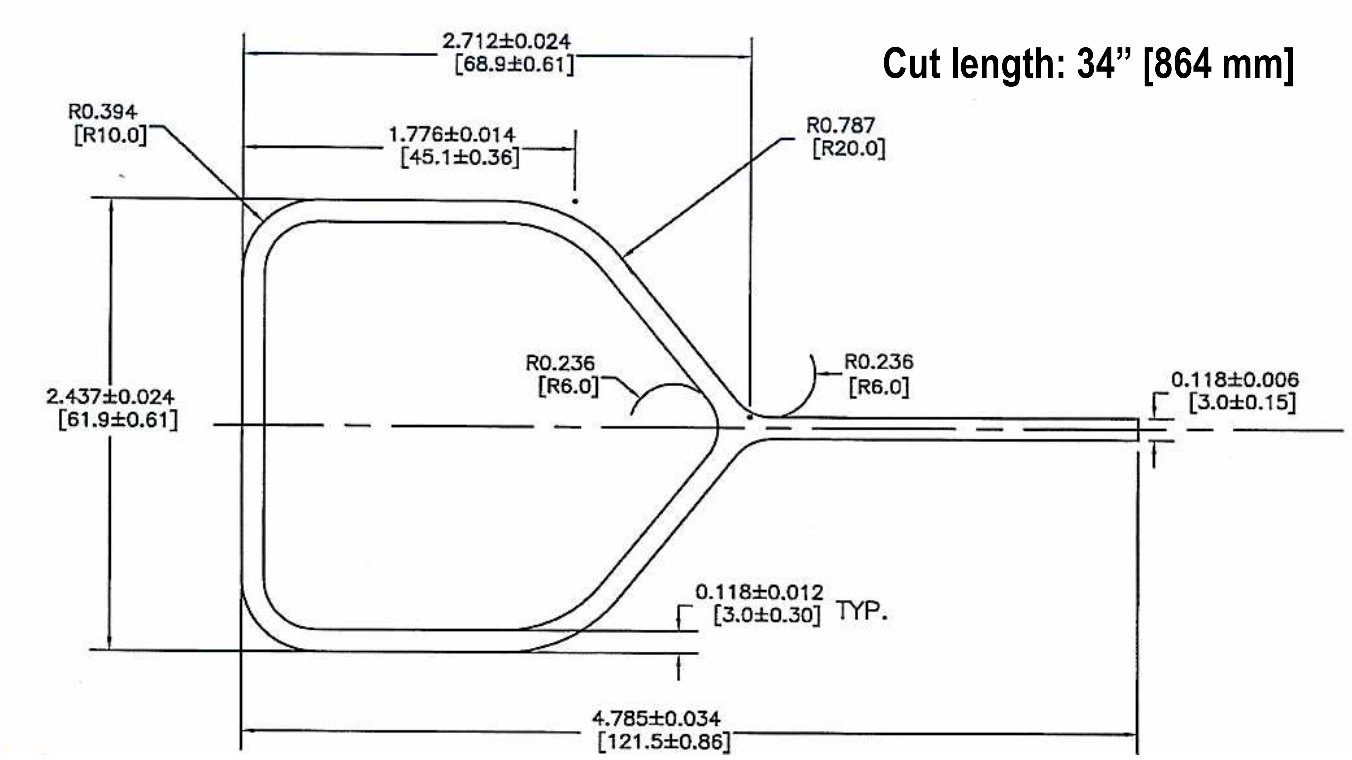


Mg/Al joint with aluminized SPR rivet (from Henrob)

FY2012 Accomplishments - Task 6 Extrusion

- "Secured" the supply of a new high-ductility Mg alloy billets: ZE20 (Mg-2%Zn-0.2%Ce)
- Ordered AA6082 aluminum extrusion plate samples for coupon testing and rails for "demo" build

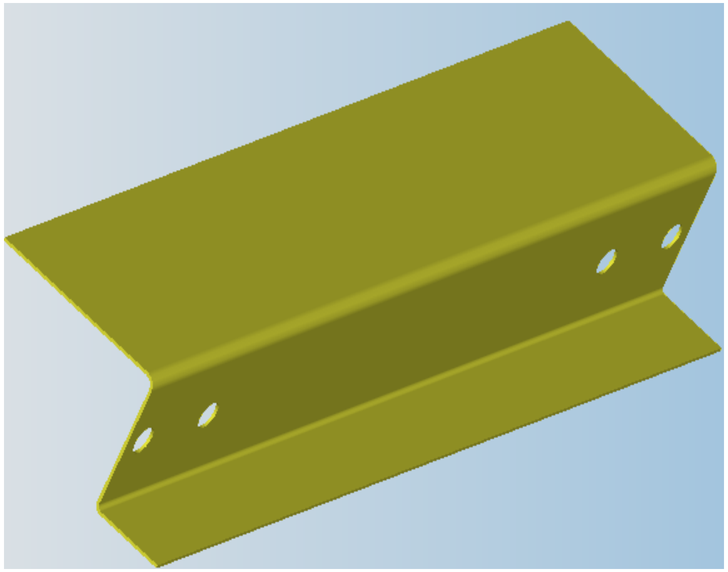
Lower rail for "demo" structure (all dimensions in inch [mm])



FY2012 Accomplishments - Task 7 Low-Cost Sheet and Forming

- Identified the sources of steel and aluminum sheets for "demo" build
- Developed the work plan to form steel and aluminum upper rail structures
- Modified designs of materials and tooling to accommodate the thinner steel sheet (1 mm) and aluminum sheet (1.5 mm) compared to Mg sheet (2 mm)
- Conducted tryout door inner panels with Canadian team using a new Mg sheet alloy: ZEK100 (Mg-1%Zn-0.1%RE-0.1%Zr)

Upper rail for "demo" structure



ZEK100 door inner (1.2 mm thickness)

FY2012 Accomplishments – Task 8 High Integrity Casting

- Modified the shock tower tool for improved die fill, joining interfaces and durability testing
- Provided AM60B ingots and casting simulations to SVDC casting trials at CANMET

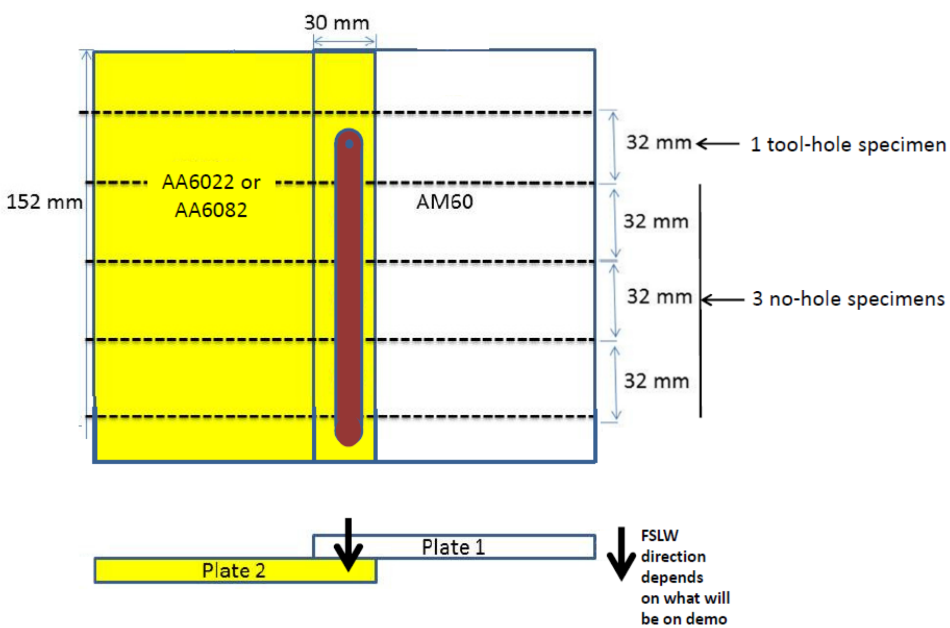
SVDC shock tower simulation

SVDC shock tower castings

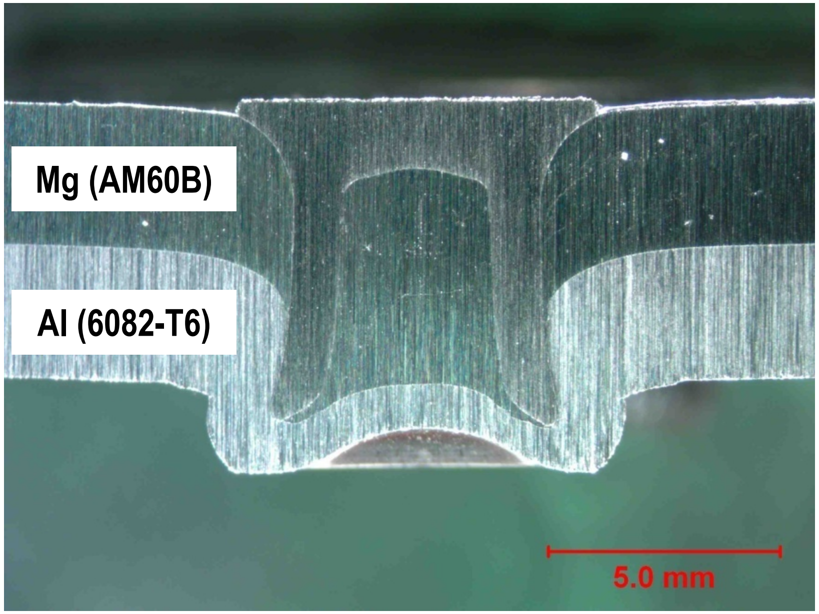
FY2012 Accomplishments - Task 9 Welding and Joining

- Developed multi-joint coupon configurations for multi-material joining trials and testing
- Down-selected joining techniques for "demo" build and initiated coupon trials such as self-pierce rivet (SPR) joints of Mg (AM60B) casting to Al (6082-T6) extrusion

FSLW test coupon configuration



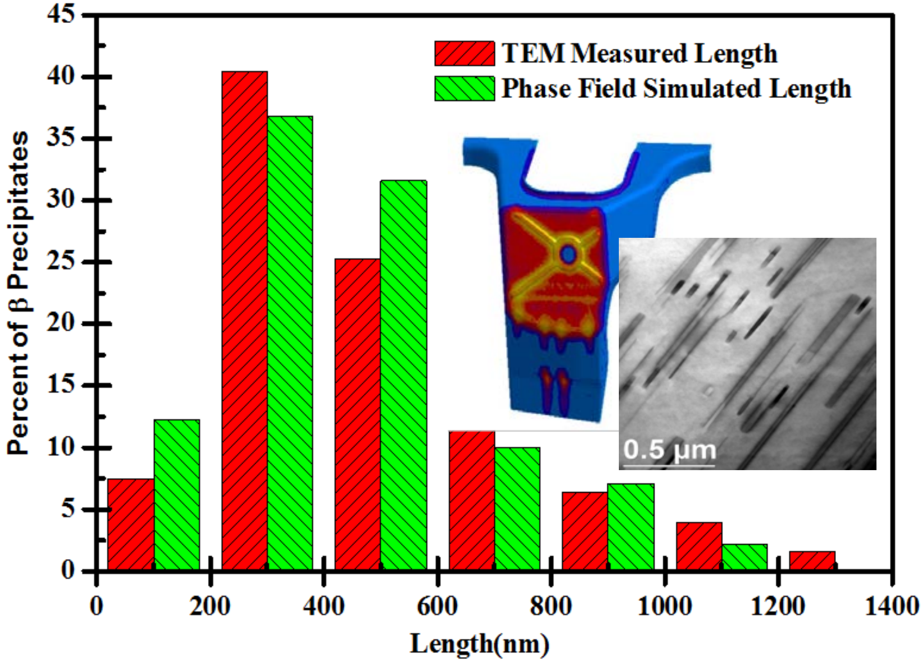
Initial self-pierce rivet joint of Mg-to-Al



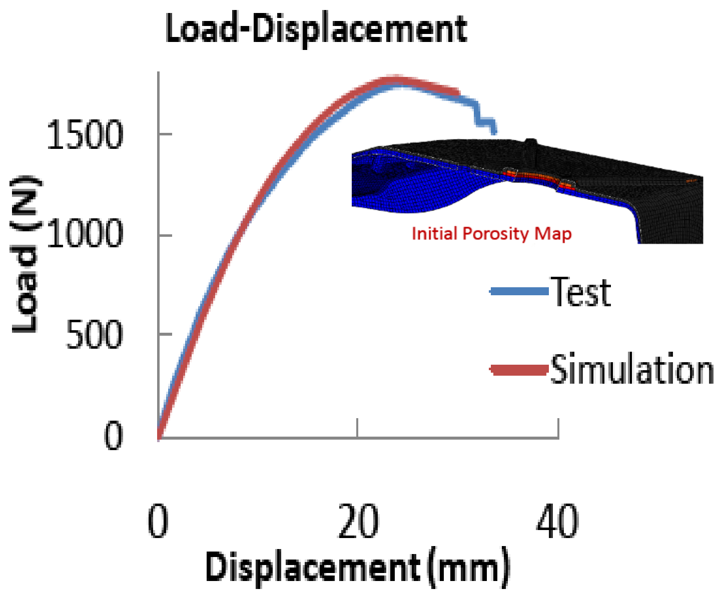
FY2012 Accomplishments – Task 10 ICME

- A hybrid phase-field / transmission electron microscopy (TEM) approach has been developed to quantify the evolution of $Mg_{17}Al_{12}$ precipitates in AZ91 Mg alloys.
- Both experimental and first-principles data were successfully incorporated.
- Local porosity was mapped to FEA model to predict the monotonic load to failure
- Microstructural and preliminary yield strength model were integrated into casting process model

Comparison of calculated and measured length distributions for beta phase precipitates in an AZ91D shock to micrograph



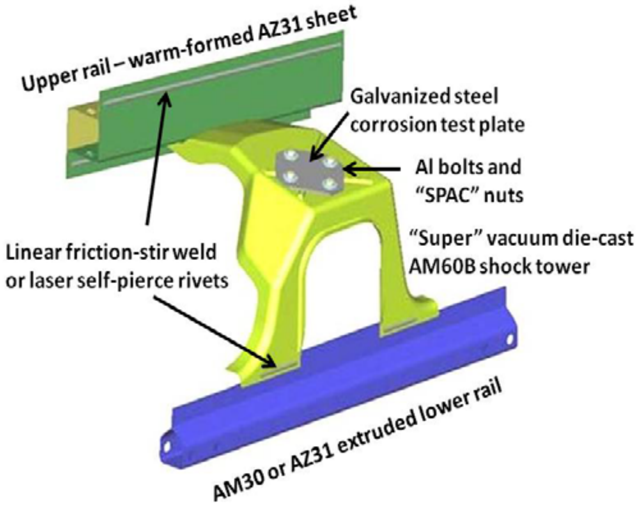
Load displacement curves from numerical and experimental testing of the shock tower with the porosity from casting process simulations



Collaboration and Coordination

- Broad participation of domestic OEMs, suppliers and universities (25 in total)
- Project executed at task level (10 teams) and coordinated by a USAMP core team
- Centered and coordinated around a "demo" structure as a focal point
- The first-of-its-kind US-Canada-China collaboration, leveraging significant international resources on coordinated pre-competitive research

USAMP "demo" structure (Phase II)



US-Canada-China working meeting in June 2012

Summary

- Successfully kicked-off project with all tasks running Expanded the scope to a multi-material “demo” structure to include magnesium, aluminum and steel components to address the critical challenges of multi-material design, manufacturing and performance
- Completed the multi-material “demo” design and started groundwork in all nine task areas

Future Work

- Joining, corrosion protection and durability (fatigue) validation of selected dissimilar material couples.
- Production of “demo” structure component parts: upper rails, shock tower and lower rail from selected materials
- Development of an assembly framework for production of “demo” assemblies and trials where appropriate.
- Continued development of more deformable grades of magnesium extrusion (ZE20) include acquisition of billet stock and trial runs with Mag Specialties.
- Completion of ICME “fatigue” studies of MFERD Phase II “demo” and initial investigation of the ICME of extruded 6082 aluminum and ZE20 magnesium.