Magnesium Front End Research and Development (MFERD)

Project ID "LM008"

AMD 603, 604 and 904

2011 DOE Merit Review Presentation

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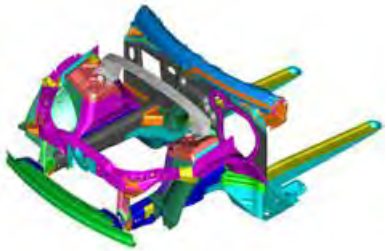
General Motors Global Research and Development



Unibody Body Front End – Steel Baseline

Acknowledgement

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AMD603:
Magnesium Front End Design and Development

Timeline

- ❑ Start: Oct. 1, 2006
- ❑ End: Sept. 30, 2009
- ❑ 100% complete

Budget

- ❑ Total project funding
  - DOE: $1.1 M
  - USAMP: $1.5 M
- ❑ Funding received in FY08: $282.1 K
- ❑ Funding for FY09 : $760.9 K
- ❑ Funding for FY10: $0 (Project ended FY09)

Barriers/targets

- ❑ Mg application in primary load-path body structures for mass saving with equivalent performance
- ❑ Design and engineering simulation of Mg body structures
- ❑ Technical cost modeling of lightweighting with Mg applications

Partners

- **OEMs**: Chrysler, Ford, GM
- **Design**: Cosma Engineering
- **Technical Cost Modeling**: Camanoe Associates

AMD604:

Magnesium Front End Research and Development (MFERD) – Phase I

Timeline

- Start: Oct. 1, 2006
- End: March 31, 2010
- 100% complete

Budget

- Total project funding
  - DOE: $1.5 M
  - USAMP: $2.7 M
    - Canada: $3M (U.S. Equiv.)
    - China: $3M (U.S. Equiv.)
- Funding received in FY09: $645 K
- Funding for FY10: $225 K (project ended in FY10)

Barriers/targets

- Improved high-volume manufacturing techniques for Mg casting, extrusion, and sheet forming
- Improved high-volume manufacturing techniques for joining and corrosion protection of Mg structures
- Improved knowledge base in Mg crashworthiness, NVH (noise, vibration and harshness), fatigue and durability

Partners

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

AMD904:

Magnesium Front End Research and Development (MFERD) – Phase II

Timeline

- Start: April 1, 2010
- End: Sept. 30, 2011
- 30% complete

Budget

- Total project funding
  - DOE: $1.214 M (through 9/30/11)
  - USAMP: $1.214 M
    - currently booked $347 K
    - Canada: $1.2M (U.S. Equiv.)
    - China: $1.2M (U.S. Equiv.)
- Funding received in FY10: $114 K
  - Funding for FY11: $1.1 M

Barriers/targets

- Demonstration of Mg casting, extrusion, sheet and joining techniques in automotive body structures
- Performance Validation of Mg crashworthiness, NVH (noise, vibration and harshness), 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 (MFERD Phase I & II)

Cosma Engineering
University of Dayton – Research Institute
IAC Corporation
Westmoreland Testing
Henkel U.S.
PPG Industries
Chemetall Oakite
MetoKote
Atotech
MacDermid
Luke Engineering
University of Michigan – Dearborn
Ohio State University
Eastern Michigan University
Contech U.S., LLC
Scientific Forming Technologies Corp.
Lehigh University
North Dakota State University
Mississippi State University
Magni Industries
Keronite
International Hardcoat Corp.
Dow Automotive
Visteon Inc.
MNP Corp.
ATF Inc.
Kamax LP
REMINC
Hitachi America
North American Die Casting Assn.
Gibbs Die Casting
EKK Inc.
Timminco Corp.
U.S. Magnesium Corp.

International Partner Organizations (MFERD Phase I & II)

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.
University of Toronto
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
Dalian University of Technology
Shanxi Yingguang Magnesium

Overall Objectives

- Develop key enabling technology for lightweight Mg applications in automotive body structures
- Design, build and test a "demo" structure for technology validation and demonstration
- Establish OEM-supplier-academia and US-China-Canada international collaborations in Mg automotive applications

General Targets

- Mass reduction up to 60% less than steel comparator; 35% less than aluminum comparator structure
- Neutral or slight cost penalty compared to steel baseline
- Vehicle performance attributes comparable to baseline structures

FY2010 Targets

- Design and select “demo” concept for final analyses , build and testing
- Select Mg alloys and manufacturing processes for “demo” build and testing
- Plan and coordinate test matrix for “demo” testing and validation
- Host international review meetings in Michigan, October 2010

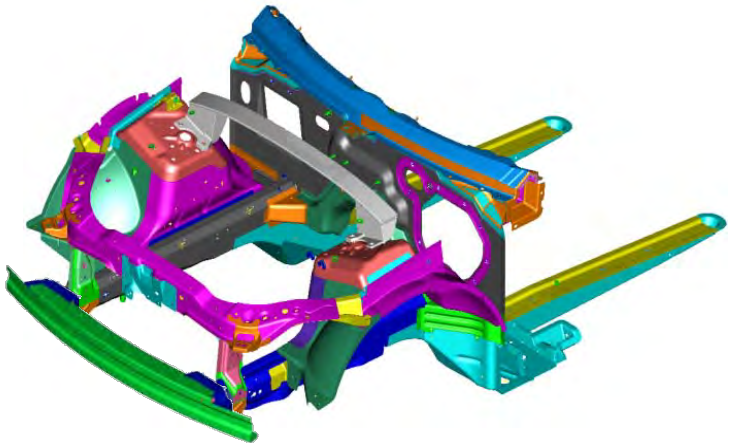
FY2010 Milestones

- Completed "Magnesium Front End Research and Development Phase I Summary Report: A Canada-China-USA Collaborative Research and Development Project", and passed final technical review with international Project Steering Committee (including DOE representatives) in March 2010.
- Generated six concepts and selected one final design for "demo" build and testing in October 2010.
- Hosted in the 4th International Review Meeting in Ann Arbor, Michigan on October 25-27, 2010, and contributed to 3rd progress "Proceedings" (529 pages) of the international project released at the Canada meeting.

Unibody (BFI) Front End Design Summary

(AMD603: Magnesium Front End Design and Development)

Baseline: 2008 Cadillac CTS



Steel baseline design
110 Parts & 99.6 kg

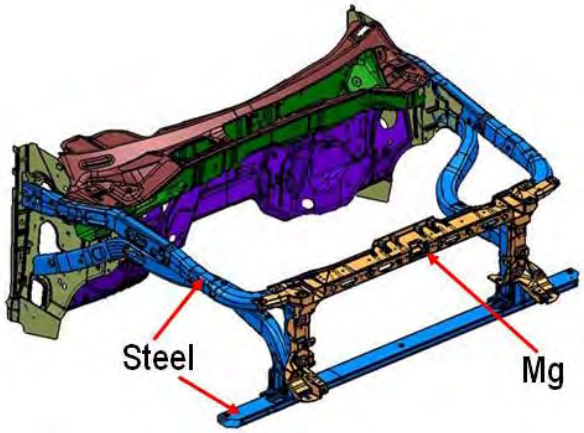
Mg-intensive design
47 Parts & 55.3 kg

44.3 kg mass reduction (44.5%)
63 part reduction (57.3%)

Body-on-Frame Front End Design Summary

(AMD603: Magnesium Front End Design and Development)

Baseline: 2009 Ford F150



Steel baseline design
20 Parts & 57.1 kg

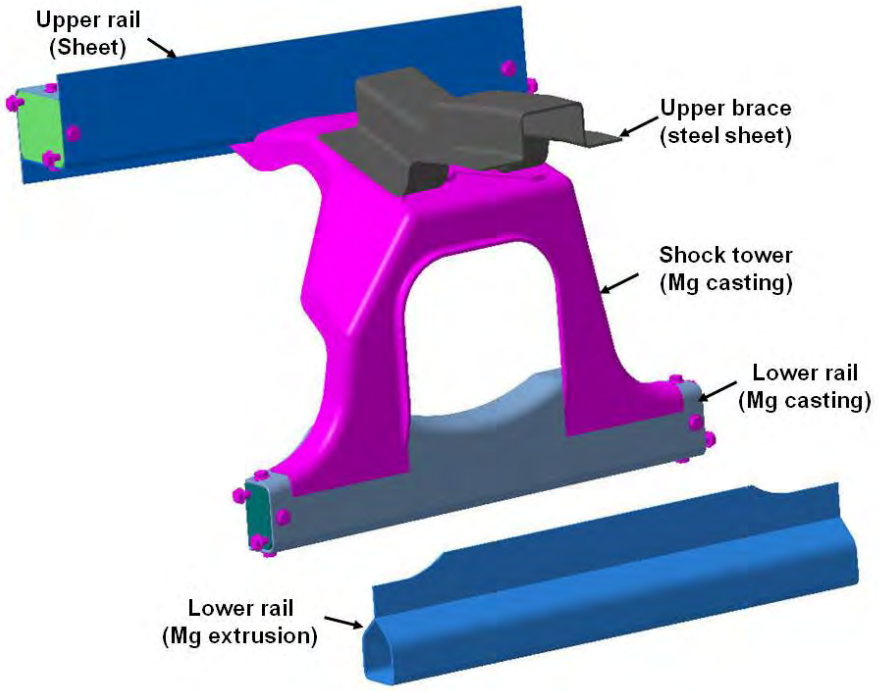
Magnesium design
18 Parts & 42.9 kg

14.2 kg mass reduction (24.9%)
2 part reduction (10%)

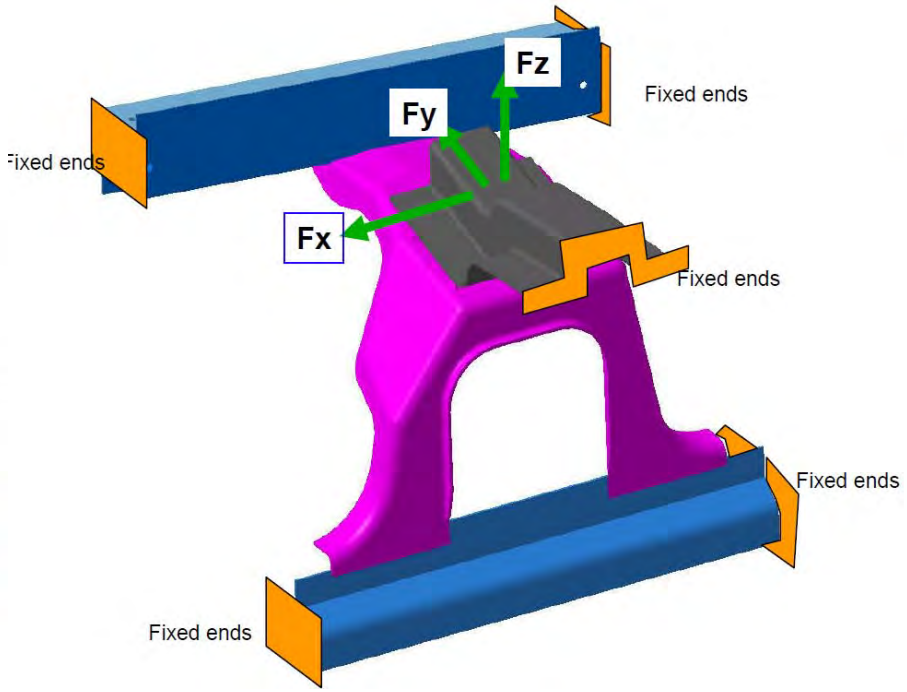
FY2010 Accomplishments - Task 2.0 Demo Design, Construction and Analysis

- Generated six concepts and selected one final design for "demo" simulation, build and testing

"Demo" design



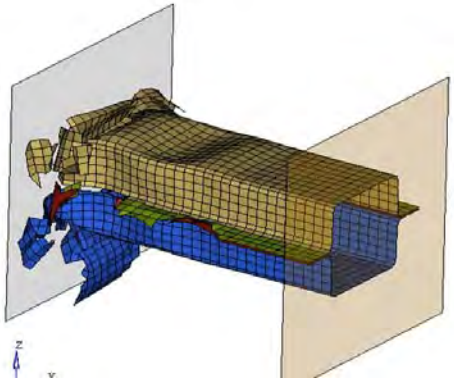
Proposed test loading

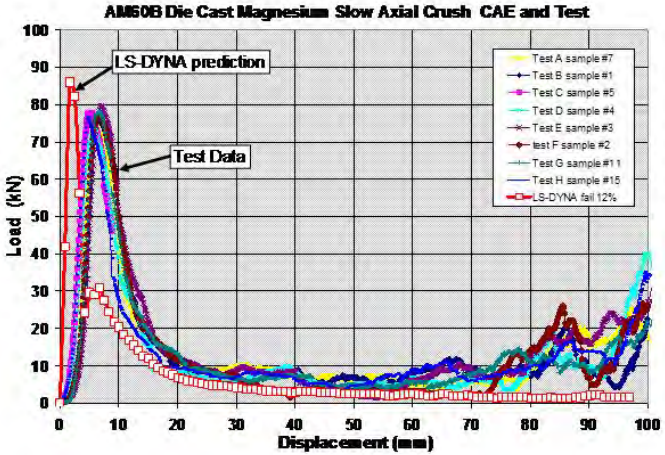


FY2010 Accomplishments - Task 2.1 Crashworthiness

- Exercise and validate "best" material model in LS-DYNA for super-vacuum die casting (SVDC) AM60 alloy

Crash testing and simulation of Mg castings

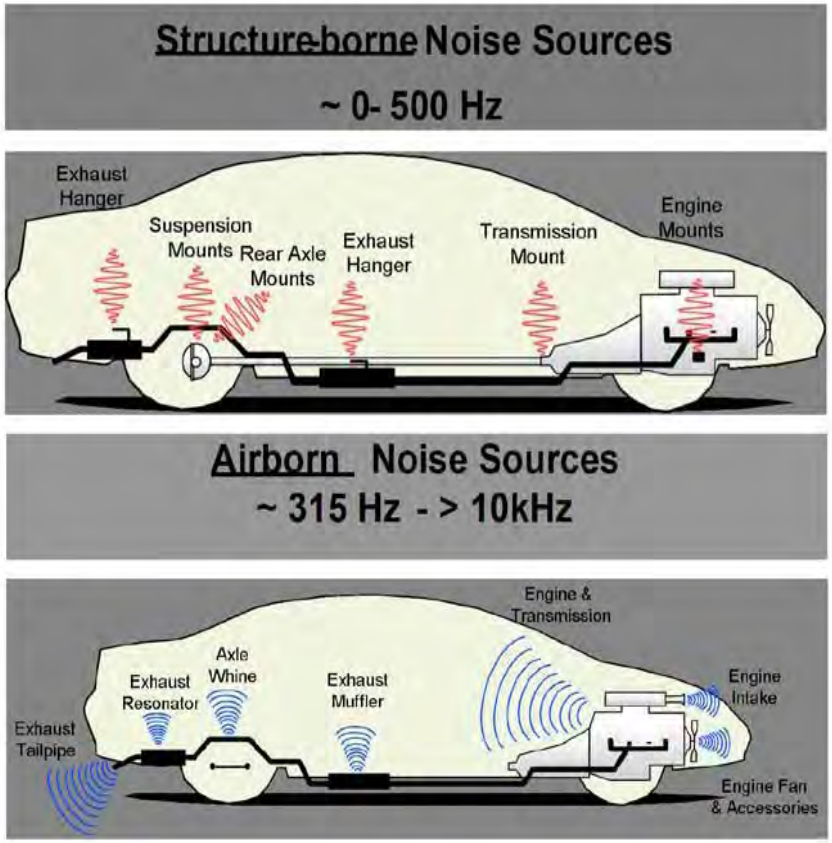




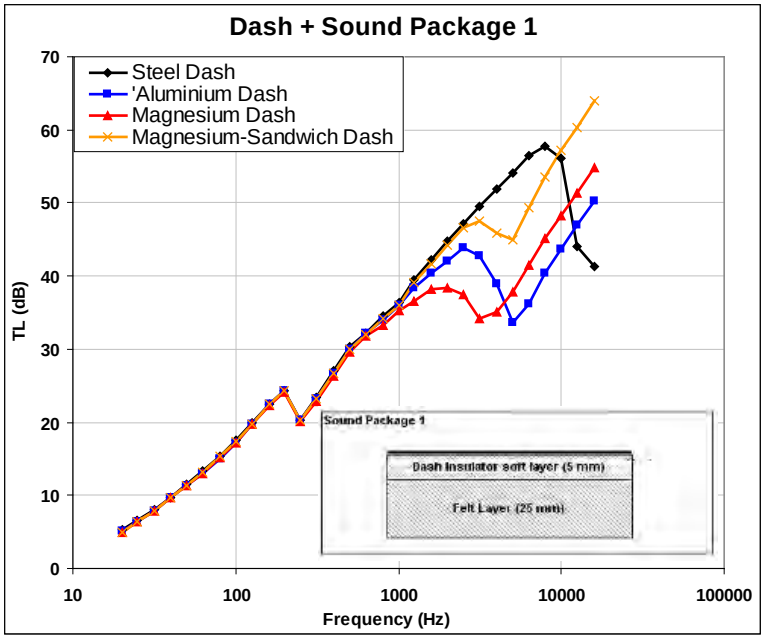
FY2010 Accomplishments - Task 2.2 Noise, Vibration and Harshness (NVH)

- Provided Viper dash panel parts (Mg die casting) to China and Canada for NVH analysis
- Verified acoustic performance (noise reduction) of Dodge Viper dash (bare and with current sound package)

Automotive noise sources



Mg dash panel NVH analysis

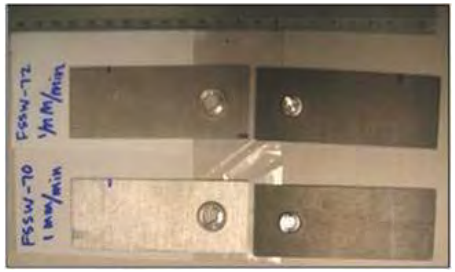


FY2010 Accomplishments - Task 2.3 Fatigue and Durability

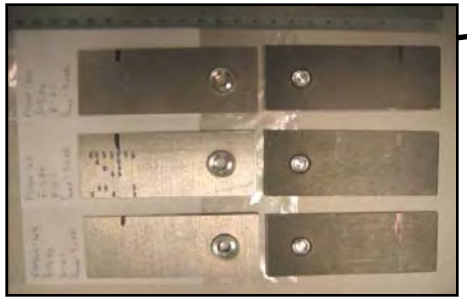
- Completed Round-Robin fatigue testing Mg AZ31 friction stir spot welds of 4 different labs in US, Canada and China

Fatigue and monotonic failure analysis

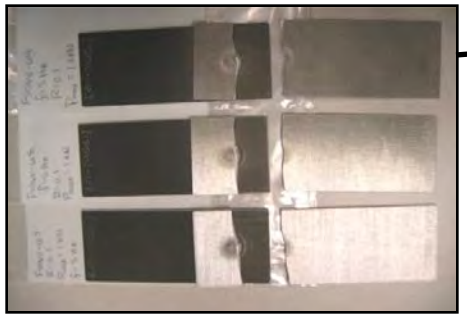
Monotonic Fracture



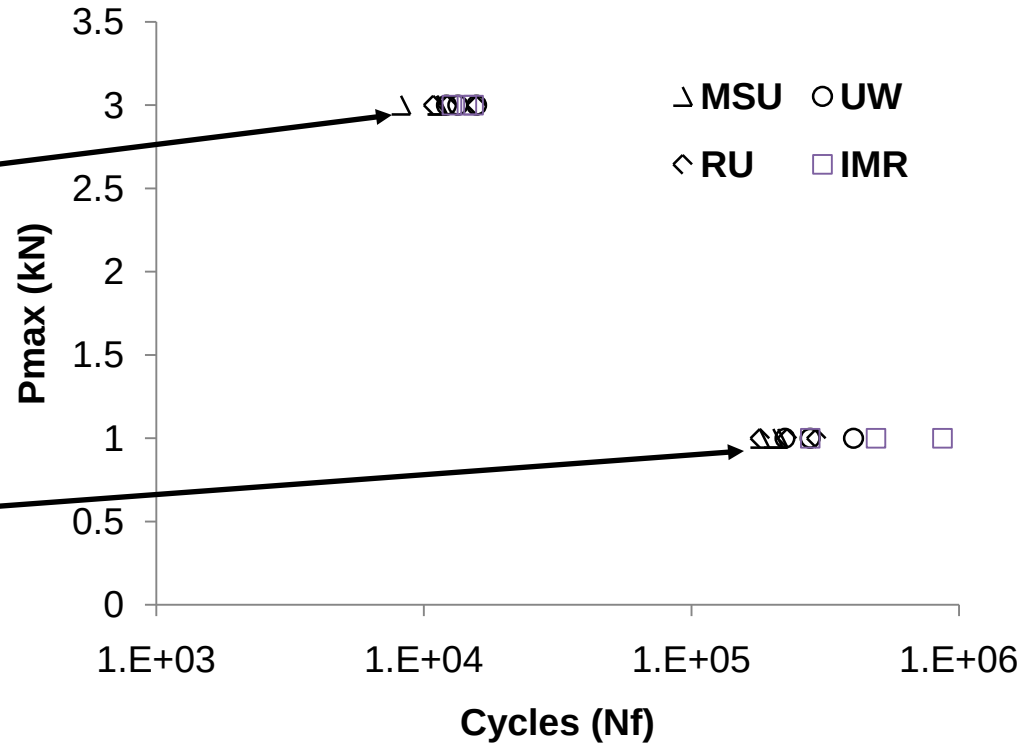
Cyclic 3 kN



Cyclic 1 kN



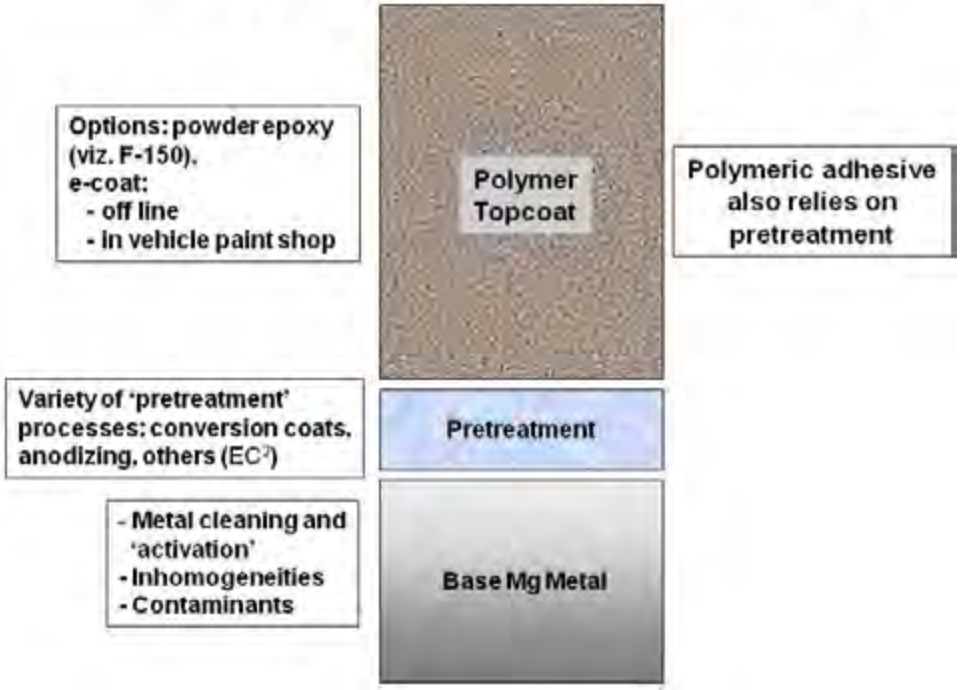
Round-Robin fatigue testing results of Mg AZ31 friction stir spot welds



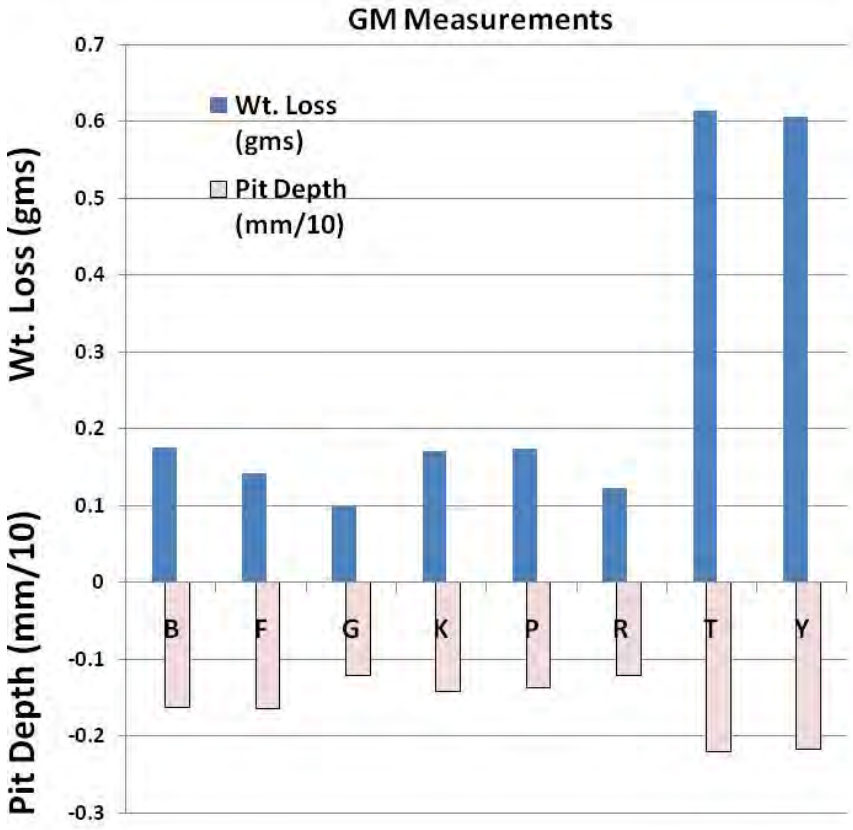
FY2010 Accomplishments - Task 2.4 Corrosion and Surface Finishing

- Established the model corrosion protection system for "demo" build and testing
- Completed OEM assessment and developed joint recommendation for cyclic corrosion testing of structural features

Model Corrosion Protection System for Magnesium



Corrosion test results of various fastener coatings

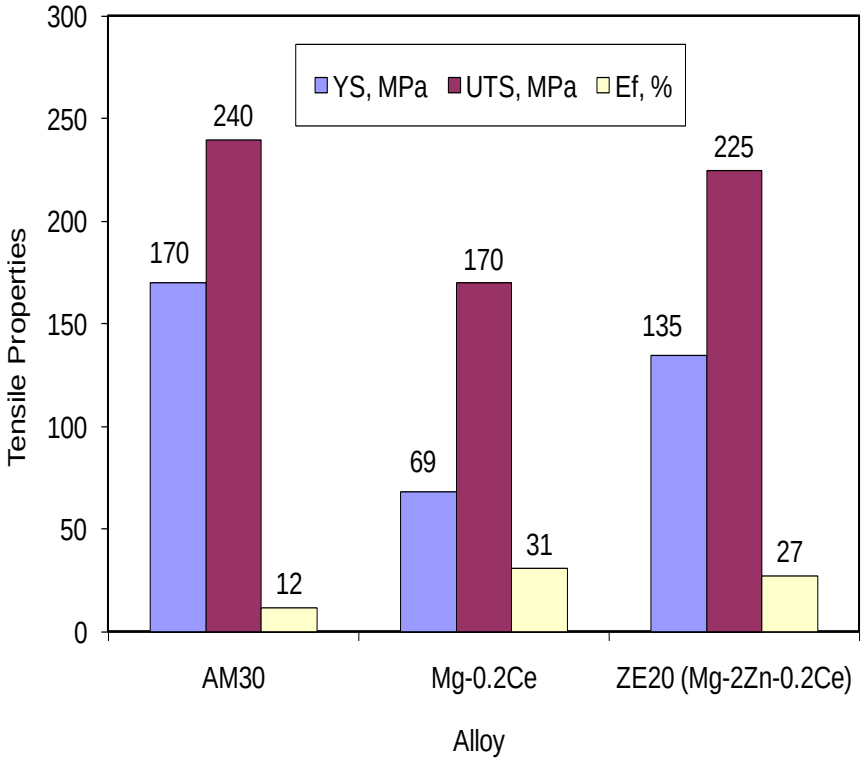


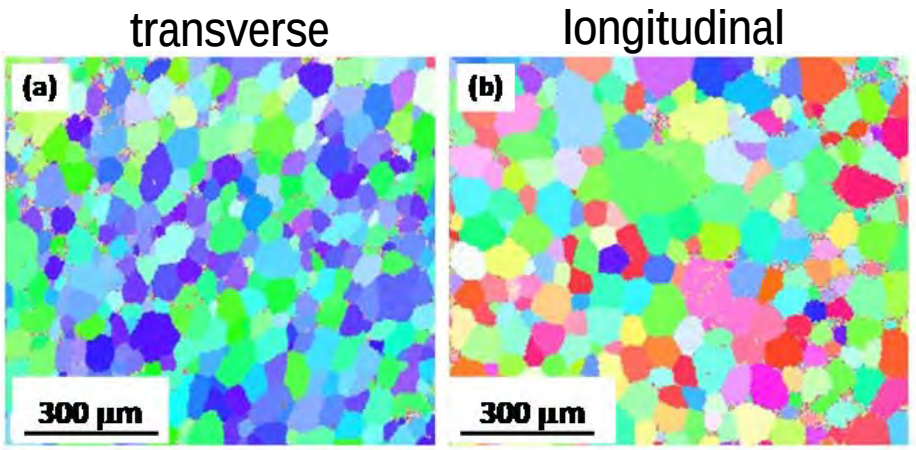
FY2010 Accomplishments - Task 2.5 Low-Cost Extrusion and Forming

- Identified a new high-ductility alloy: ZE20 (Mg-2%Zn-0.2%Ce) developed by GM

Improved ductility (125% improvement) in ZE20 alloy

Randomization of texture and the low peak intensity in ZE20 alloy

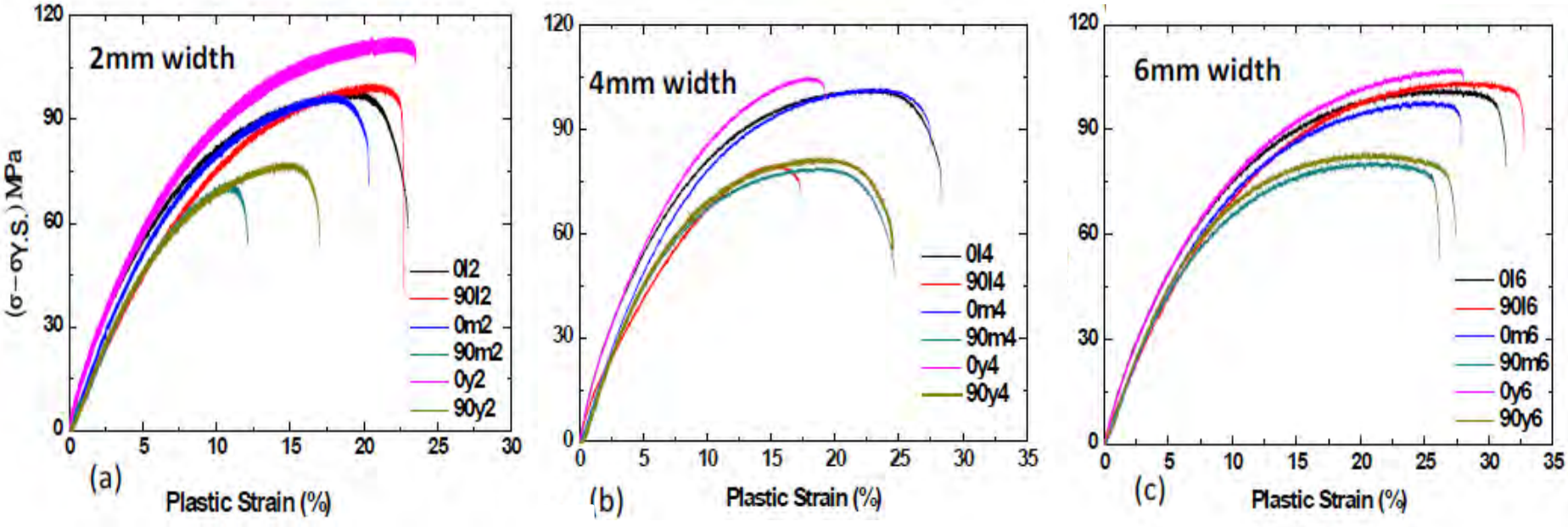




FY2010 Accomplishments - Task 2.6 Low-Cost Sheet and Forming

- Evaluated the formability of various Mg sheet materials produced by direct-chill (DC) cast and CC processes for "demo" build

Sheet evaluation results



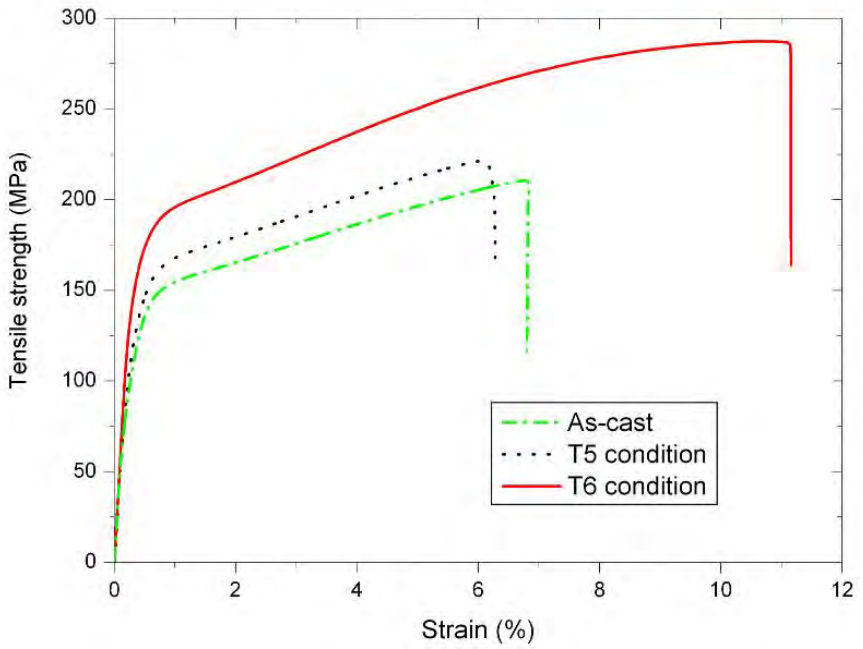
FY2010 Accomplishments - Task 1.7 High Integrity Body Casting

- Identified a high strength heat treatable magnesium alloy: NZ30 (Mg-2.5%Nd-0.5%Zn) developed in China

Tensile properties

Temper	UTS/MPa	YS/MPa	Elongation/%
NZ30 (As-cast)	211.4	153.5	6.8
NZ30-T5	223.9	168.4	6.4
NZ30-T6	278.3	187.8	11.3
Al: (Aural2-T6)	230	180	10

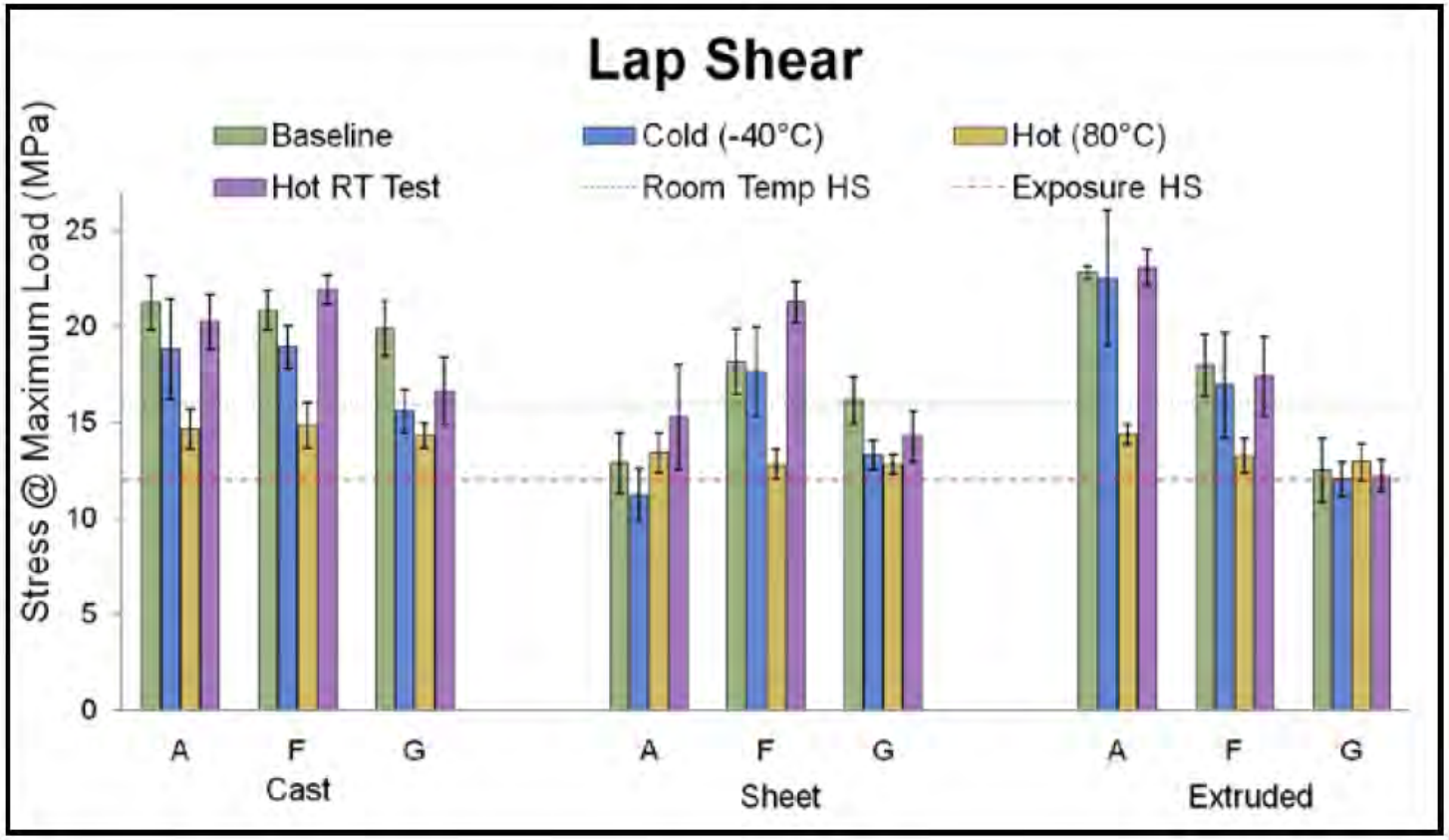
Tensile curves of NZ30 (Mg-2.5%Nd-0.5%Zn) alloy



FY2010 Accomplishments - Task 1.8 Welding and Joining

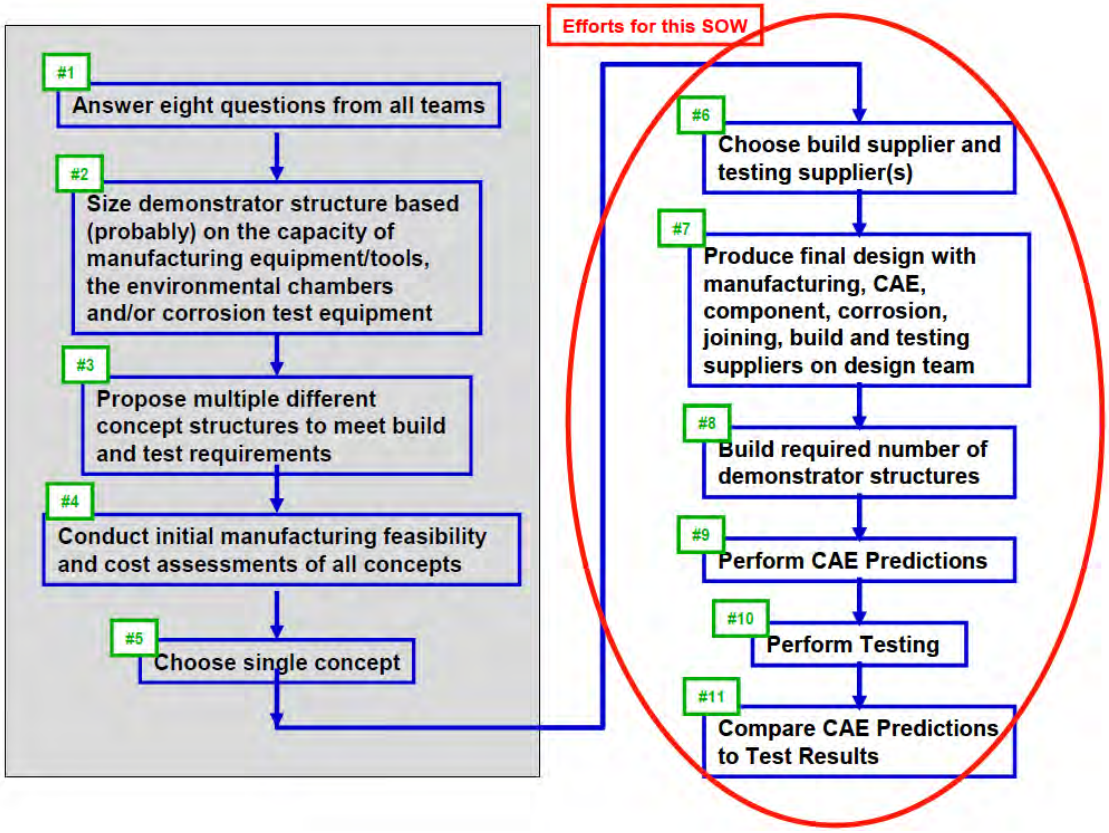
- Selected the joining techniques (friction-stir welding, self-pierce riveting with and without adhesive) for "demo" build and testing
- Completed the static testing of typical Mg joints

Lap shear test results of Mg joints



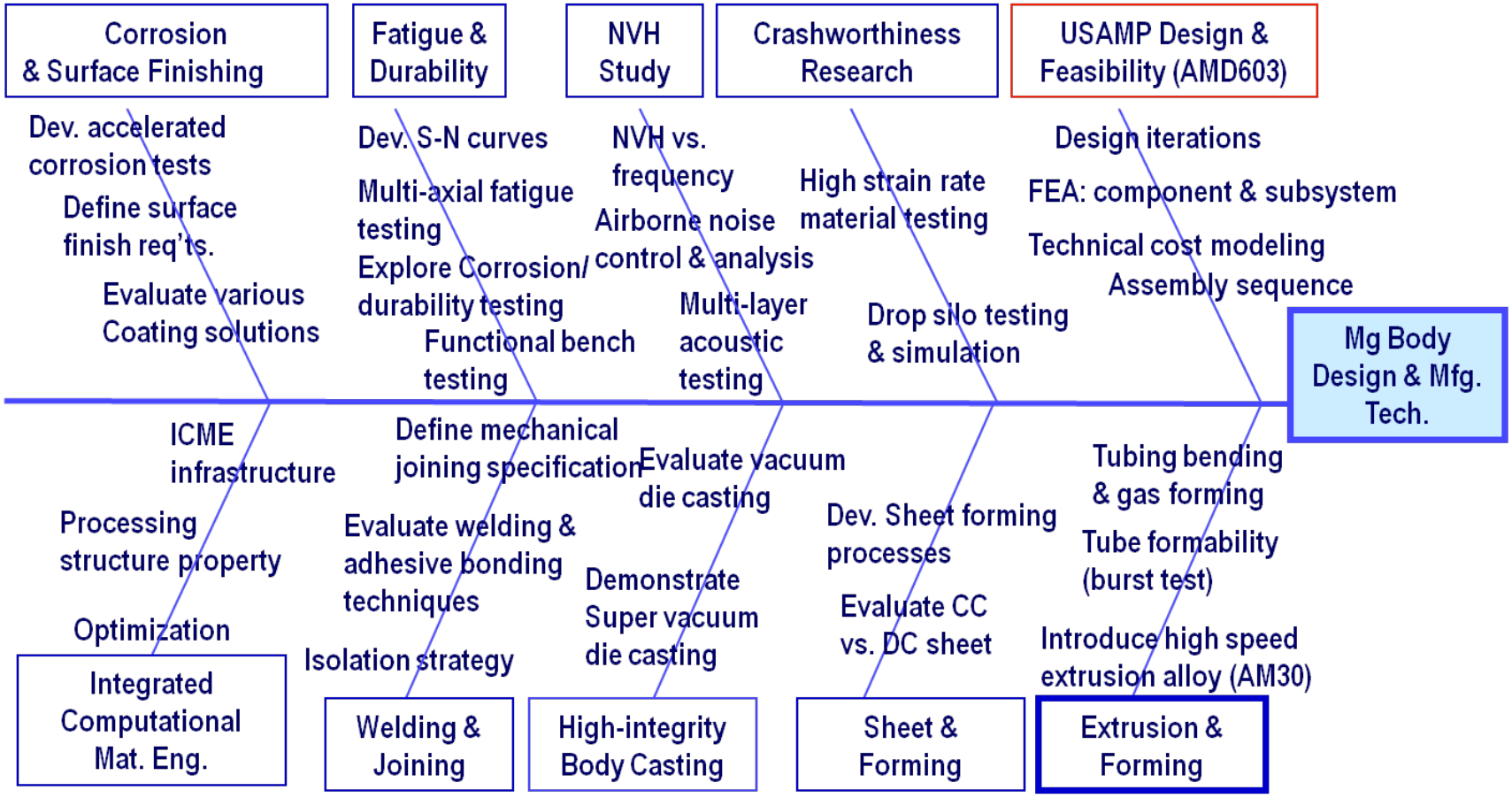
Future Work: Magnesium Front End Research & Development Phase II (AMD904)

- "Demo" final design, analyses and tested has been awarded to a general contractor
- "Demo" component manufacturing – 2Q2011
- "Demo" assembly and testing – 3Q2011
- Project completion and reporting – 3Q2011



Summary

Knowledge Base Development



Enabling Technology Development

Conclusions

- The Magnesium Front End Design and Development (AMD603) suggested that a Mg-intensive front end design can achieve nearly 50% mass reduction with equivalent performance (based on simulations) relative to A HIGHLY EFFICIENT STATE OF THE ART steel baseline for the unibody architecture based upon known manufacturing technologies and presumptions regarding joining and surface finishing technologies.

- The Magnesium Front End Research and Development Phase I project (AMD604) has developed key enabling technologies and knowledge base for Mg applications, which will be validated and demonstrated in Phase II project (AMD904) using a “demo” structure.

- As first-of-its-kind US-Canada-China collaboration, the Magnesium Front End Research and Development Project has clearly demonstrated the capability for an international cooperative research effort with multiple and complex technical disciplines and targets, resulting in the development of significant enabling technologies and knowledge based for magnesium automotive applications.