# Magnesium Front End Research and Development (MFERD)

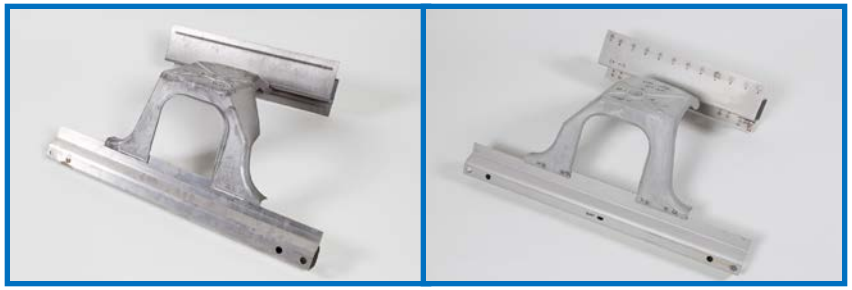
## Project ID "LM008"

AMD904

***2012 DOE Merit Review Presentation***

***Alan A. Luo***

***General Motors Global Research and Development***



**Magnesium Front End "Demo" Structure**

# Acknowledgement

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# AMD904:

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

### Timeline

- Start: April 1, 2010
- End: March 31, 2012
- 100% complete

### Budget

- Total project funding
  - DOE: $1.057 M (through 1/31/12)
  - USAMP: $1.057 M
- Funding received in FY11: $634 K
- Funding for FY12: $464 K

### Barriers/targets

- Demonstration of Mg casting, extrusion, sheet and joining techniques in automotive body structures
- Performance validation of Mg crashworthiness, corrosion, fatigue and durability

### Partners

- OEMs: Chrysler, Ford, GM
- U.S. Supplier list (slide 4)
- International Partners from China and Canada (slide 5)

# USAMP Core Team


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Steve Logan


Joy Forsmark
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David Wagner
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Ravi Verma
Yar-Ming Wang

Bob McCune, Technical Project Administrator

# 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

# Approaches

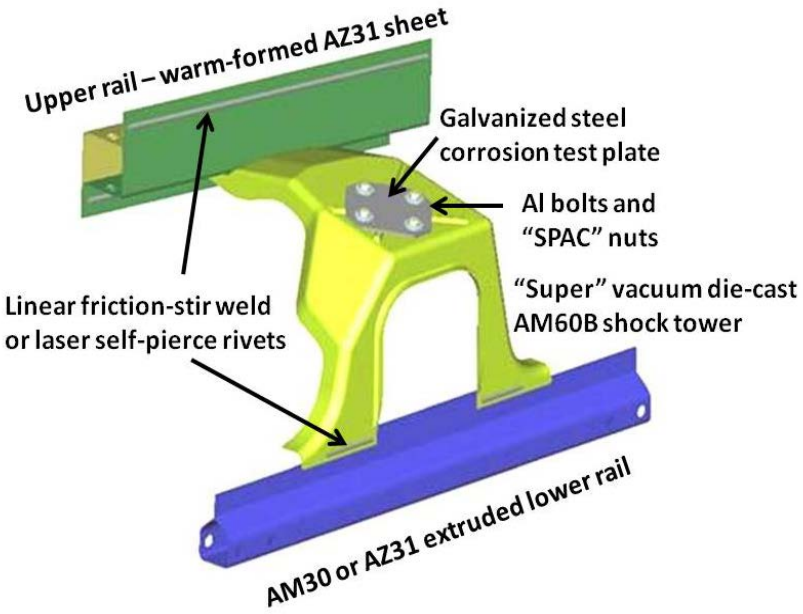
- Mass reduction of Mg-intensive body structure: up to 45% less than steel comparator; 20% less than aluminum comparator structure
- Use a “demo” structure to validate key enabling technologies and knowledge base

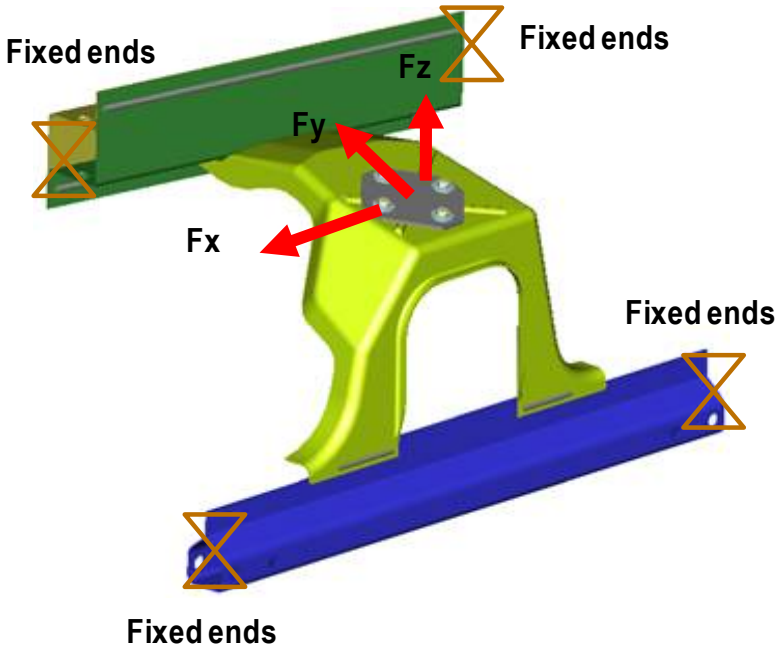
# FY2011 Targets

- Complete Mg front end “demo” structure build and testing (structural and corrosion)
- Demonstrate enabling technologies in Mg casting, extrusion, sheet forming, coating and joining
- Validate materials models in crashworthiness and fatigue

# FY2011 Milestones

- Completed the Mg front end "demo" structure build using two joining techniques
- Completed the structural (static and dynamic) and corrosion testing
- Final project report and plan for the DOE project "Development and Demonstration of a Magnesium-Intensive Vehicle Front-End Substructure" (DE-EE0005662)



# FY2011 Accomplishments - Task 2.0 Demo Design, Construction and Analysis

- Completed the Mg front end "demo" structure build using two joining techniques (about 200 structures built for testing)

"Demo" build using friction stir linear welding (FSLW) joining process

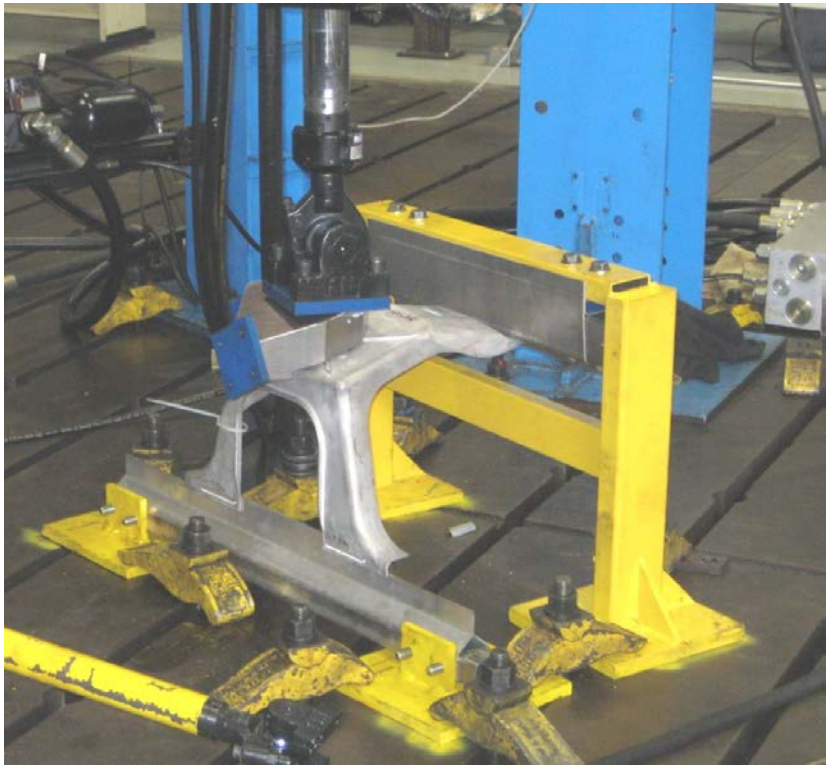
"Demo" build using laser-assisted self pierce rivet (LSPR) joining process

# FY2011 Accomplishments - Task 2.0 Demo Design, Construction and Analysis

- ❑ Completed structural testing (static and dynamic) of the "demo" structures
- ❑ Completed initial corrosion of the "demo" structures at OEM proving grounds

**Static testing of "demo" structure**

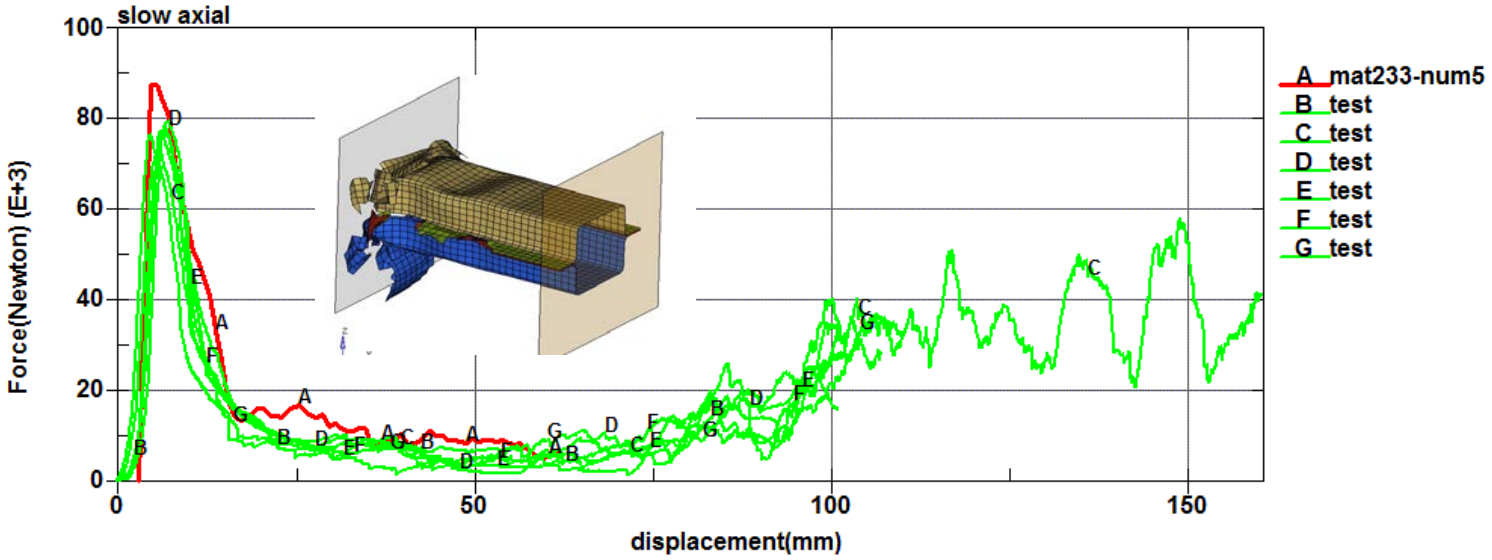
**Dynamic testing of "demo" structure**

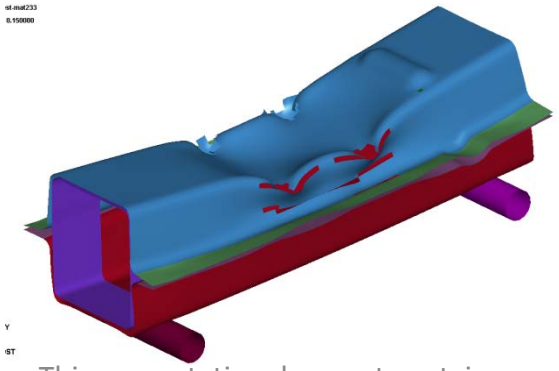


# FY2011 Accomplishments - Task 2.1 Crashworthiness

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

**Crash testing and simulation of Mg castings**



# FY2011 Accomplishments - Task 2.2 Noise, Vibration and Harshness (NVH)

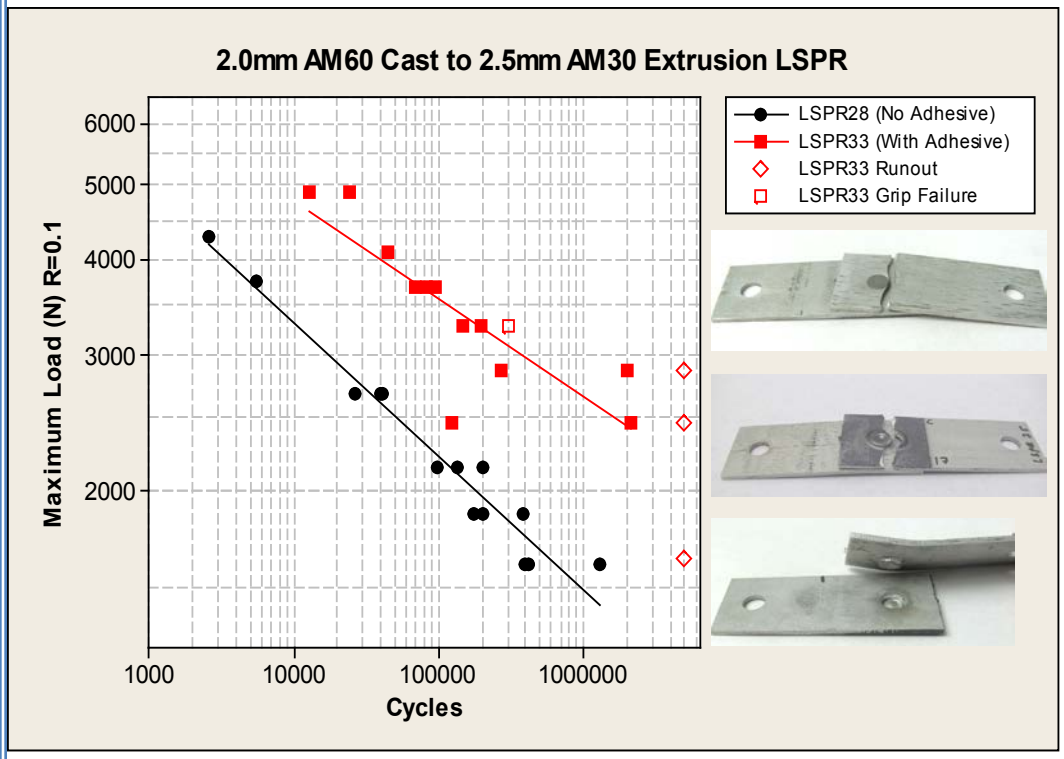
- Provided Viper dash panel parts (Mg die casting) to China and Canada for NVH analysis
- Verified acoustic performance (noise reduction) of Dodge Viper dash (bare and with current sound package)

**Mg dash panel form Dodge Viper**

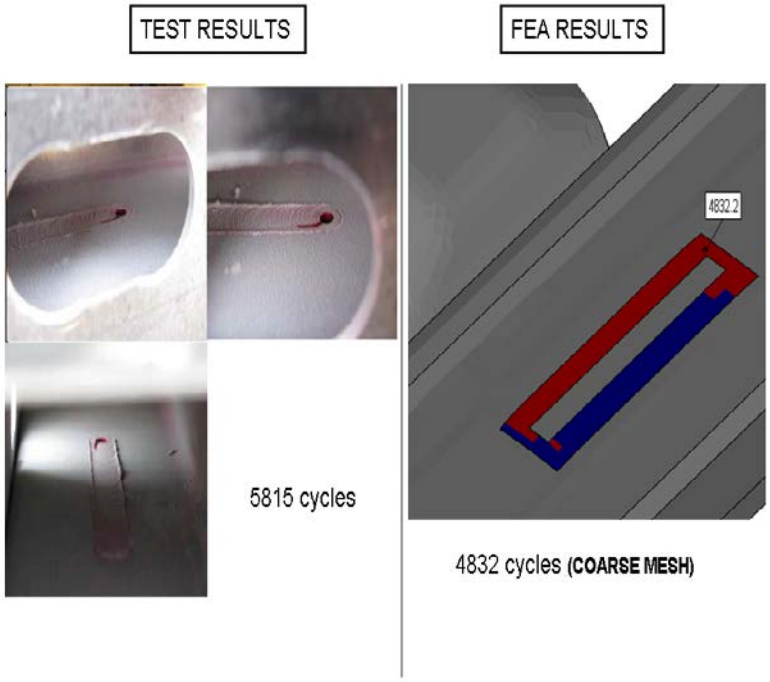
# FY2011 Accomplishments - Task 2.3 Fatigue and Durability

- Completed fatigue testing of friction-stir welding joints and self-pierce rivets
- Compared the FEA prediction of fatigue life of the "demo" structure and the actual durability testing results – some agreement but more to learn

**SPR joint fatigue test results**



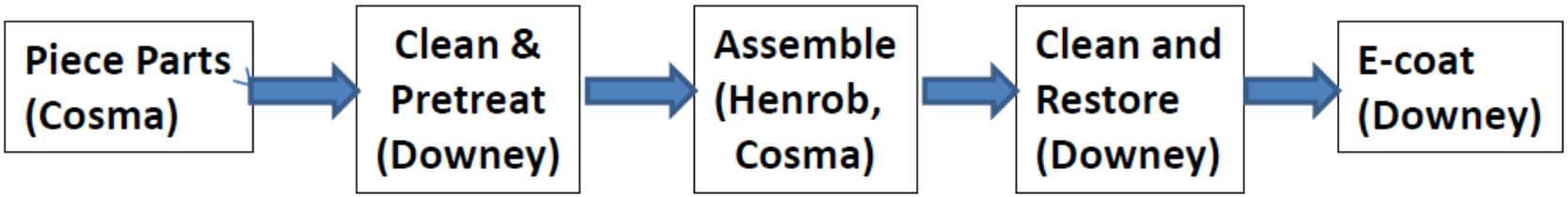

**FEA prediction and durability test results for a FSLW joint in the demo structure**



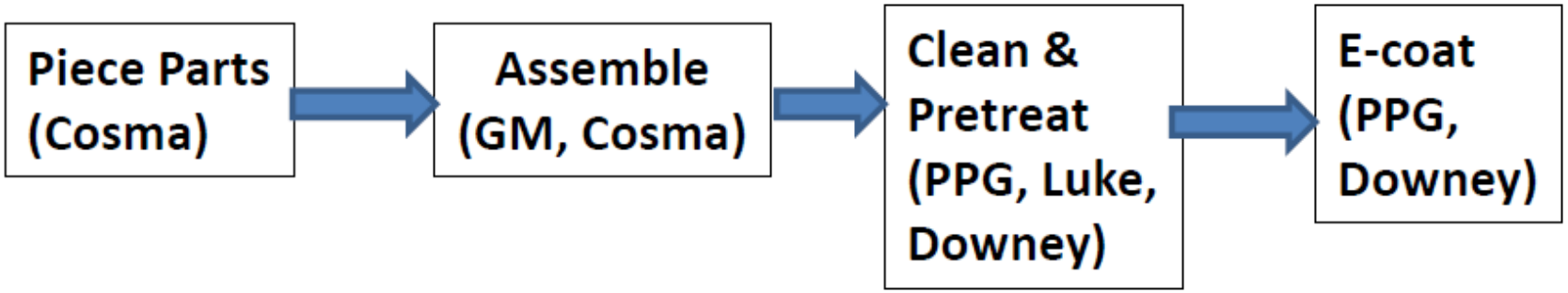
# FY2011 Accomplishments - Task 2.4 Corrosion and Surface Finishing

- ❑ Established pilot surface-processing capabilities on Henkel Alodine® 5200 pretreatment, AHC MagPass® and PPG 590-534 cathodic epoxy topcoat for "demo" structures
- ❑ Completed initial corrosion of the "demo" structures at OEM proving grounds

**Coating and joining process flow for SPR and FSW "demo" structures**



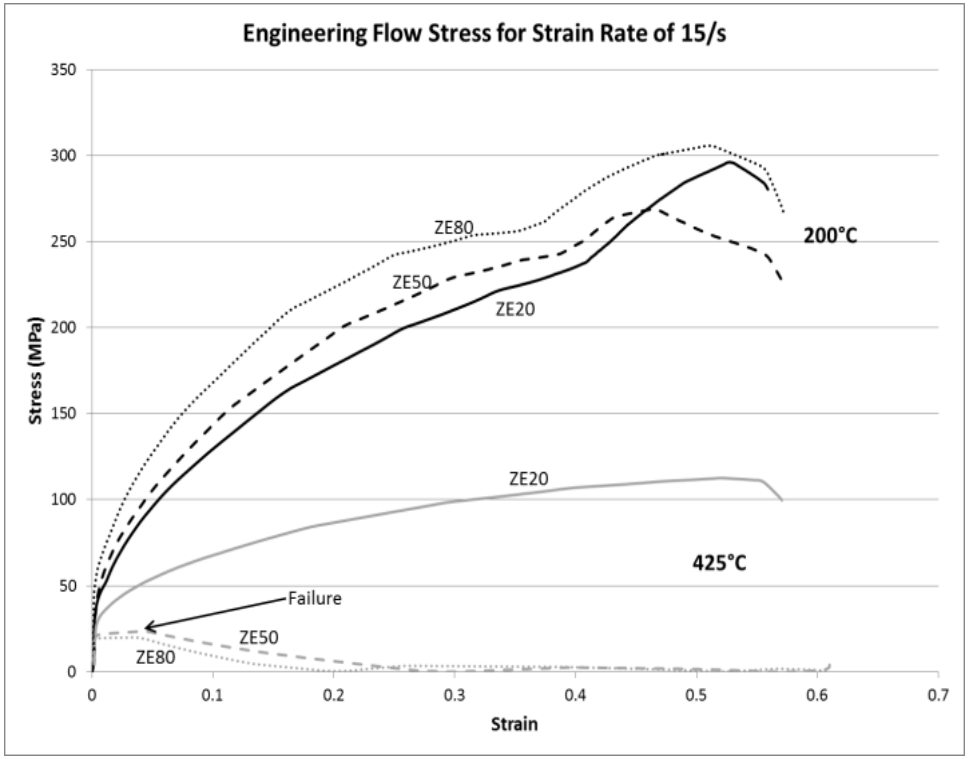

Note: Laser pre-heat SPR requires metal pretreatment.



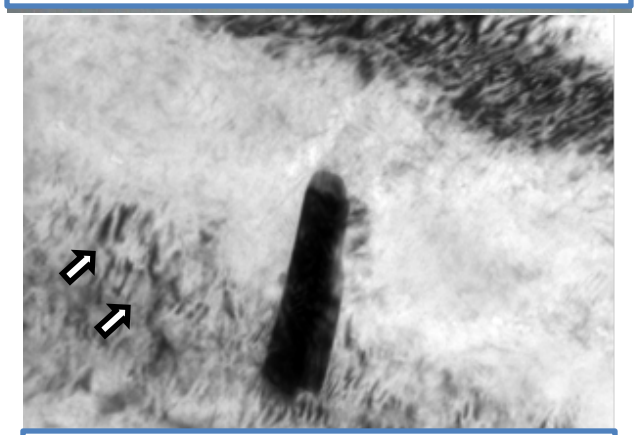
# FY2011 Accomplishments - Task 2.5 Low-Cost Extrusion and Forming

- Completed workability evolution of a new high-ductility alloy: ZE20 (Mg-2%Zn-0.2%Ce)

**Gleebe test results showing the improved workability of ZE20 alloy compared with ZE50, and ZE80**




**AM30 extrusion for "demo" build**

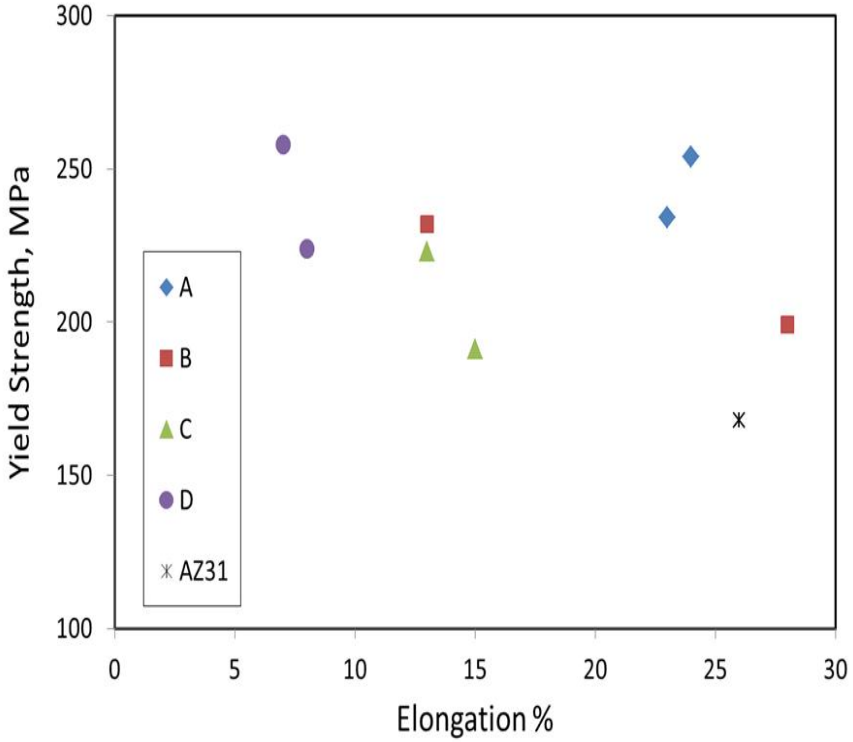


**TEM micrograph showing Ce-rich precipitate and dislocation in deformation microstructure**

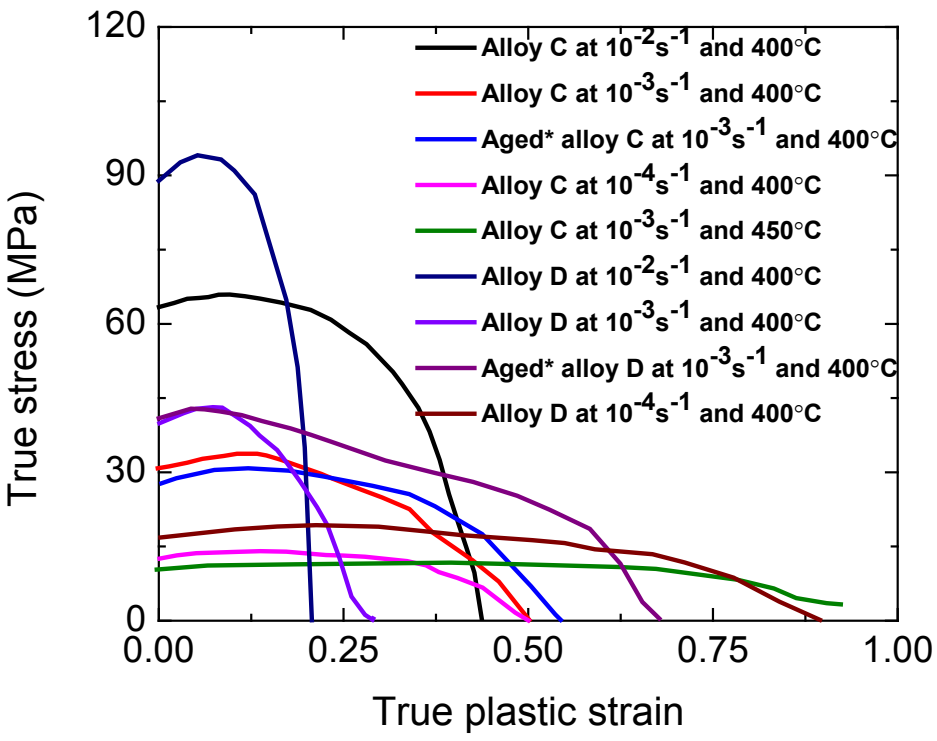
# FY2011 Accomplishments - Task 2.6 Low-Cost Sheet and Forming

- ❑ Selected Mg-Y-Al-Zn-Ce system and 4 new alloy compositions
- ❑ Completed room-temperature tensile testing of as-rolled and aged alloys
- ❑ Conducted high-temperature tensile testing of 2 alloys

**Room-temperature evaluation results of new alloys**




**High-temperature evaluation results of new alloys**

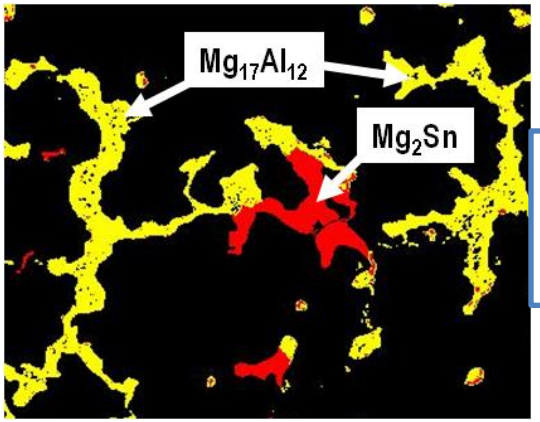


# FY2011 Accomplishments – Task 2.7 High Integrity Body Casting

- Identified two high-strength heat-treatable magnesium alloy: NZ30 (Mg-3%Nd-0.5%Zn) and AT72 (Mg-7%Al-2%Sn)

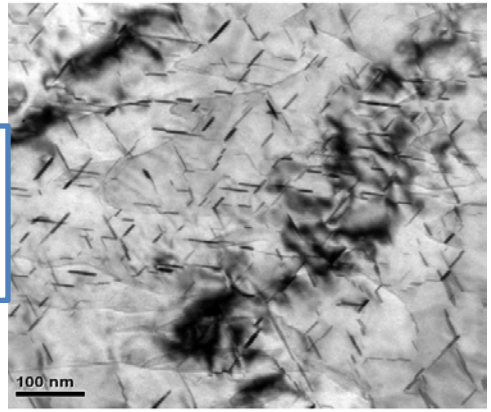
**Tensile properties**

| Alloy / Temper | Yield Strength, MPa | Ultimate Tensile Strength, MPa | Elongation, % |
|---|---|---|---|
| Mg: AZ91D (as-cast) | 150 | 200 | 3 |
| Mg: AM60B (as-cast) | 124 | 227 | 9 |
| Mg: AT72 (as-cast) | 158 | 251 | 6 |
| Mg: NZ30 (as-cast) | 154 | 211 | 7 |
| Mg: NZ30 (T6) | 188 | 278 | 11 |
| Al: Aural 2 (T6) | 180 | 230 | 10 |




As-cast microstructure of AT72 alloy

Precipitation microstructure of NZ30 alloy



# FY2011 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 "demo" build using these techniques

Friction-Stir Welding (GM)

Lab-Scale Self-Pierce Riveting (Swinbourne Univ, Australia)

Production Laser-Assisted Self-Pierce Riveting (Henrob, Novi, MI)

FSW joint in "demo"


SPR joints in "demo"

# Summary

- We have completed the magnesium front end "demo" build , testing and validation.
- We have developed and demonstrated the key enabling technologies and knowledge base for magnesium body applications.
- We have experimented the first-of-its-kind US-Canada-China collaboration, leveraging significant international resources to develop pre-competitive knowledge base and enabling technologies for magnesium automotive applications.

# Future Work

- AMD904 project final reports by June 2012
- New DOE project "Demonstration Project to Develop and Construct a Magnesium-Intensive Vehicle Front-End Substructure".
- 2012 Annual US-Canada-China Working Meeting on June 11-13 in Shanghai, China