Structural Cast Magnesium Development (SCMD) AMD 111

USAMP
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- Technology Transfer and Lessons Learned
- Future Activities (Project Closed August, 2006)
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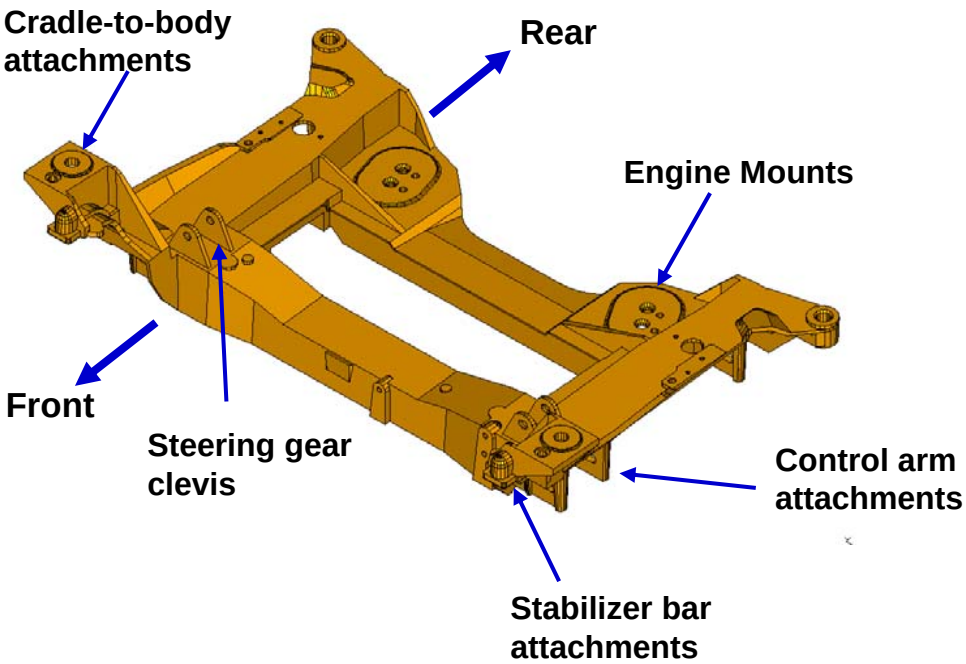
Purpose of Work

- **The SCMD Project was completed in August 2006. The key project goals during the 66 month time frame were:**
  - Overcome all known technical and manufacturing issues using cast magnesium automotive components.
  - Redesign an existing aluminum engine cradle to magnesium for the 2006 Corvette ZO6 vehicle at no cost penalty and no changes to vehicle build cradle installation sequence.
  - Validation of Mg cast component performance to vehicle requirements must be achieved or exceed the existing standards.
  - Transfer the knowledge to industry and identify the lessons learned by this project.
  - Meet all funding and in-kind support activities in accordance with the projects original Statement of Work (SOW)

Barriers

The Corvette C6 donor Engine Cradle offered many and difficult challenges for cast Mg alloy components exposed to harsh service conditions

Critical Attachments



- High service loads
- Exposed underbody placement (galvanic corrosion mitigation critical)
- Elevated temperature (125°C)
- Fixed cradle geometry
- Requirement of a new alloy

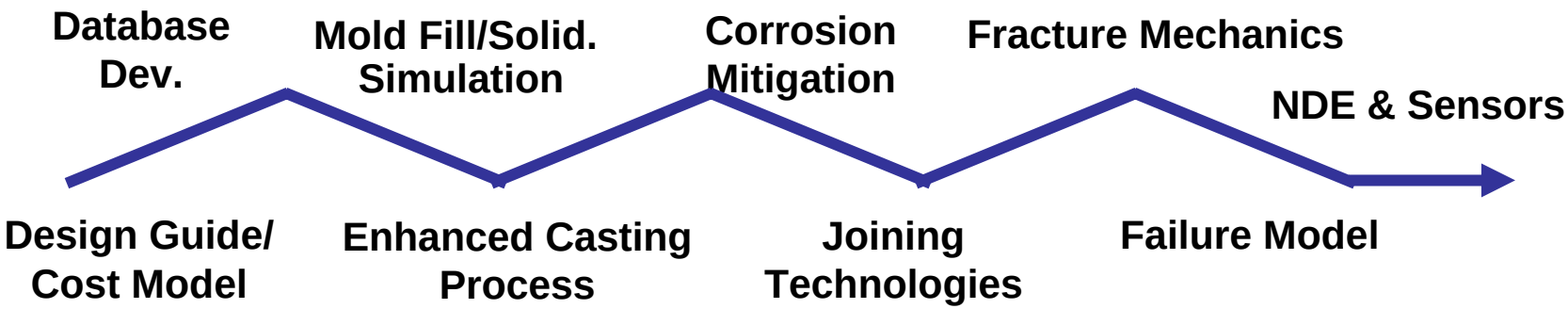
The Accomplishment of the above challenges to meet Job #1 Deadline required the joint efforts of industry and academia working closely together.

Approach

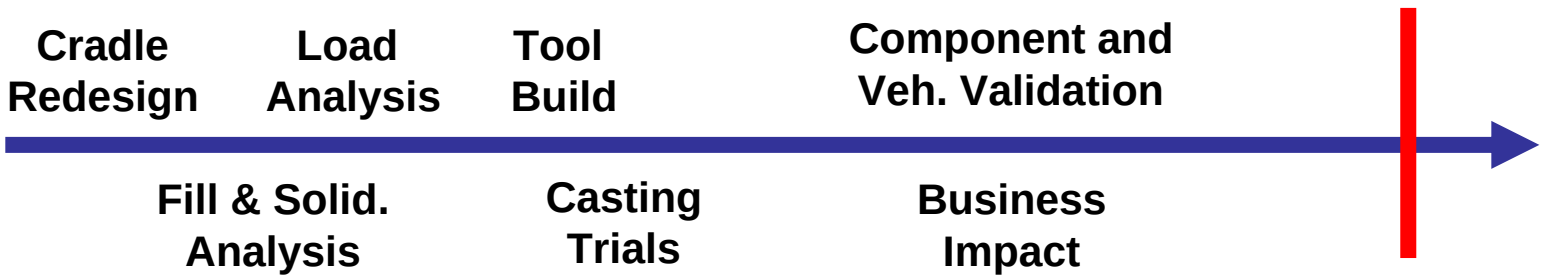
- Redesign the existing aluminum engine cradle to a Mg. engine cradle
- Provide a new Mg alloy (AE44) to limit thermal creep and ensure bolt load retention.
- Design and manufacture production type tooling to provide 150 prototype castings by December 2003 for validation and testing.
- Continue the existing “Automotive Light Material Database” to include all materials tested for the SCMD Project.
- Develop and verify positive results using the “Predictive Failure Model” for casting evaluation.
- Identify and provide solutions to the known technical and manufacturing issues associated with the use of Mg cast Components. (Dual Activity Slide with Industry and Science)
- Provide Roadmap that will guide the automotive industry’s development and use of Mg through 2006 to 2020.
- Meet Job #1 delivery date for 2006 Corvette ZO6 for first industry application of a Mg Engine Cradle.
- Issue a Final Report to all Project Participants.

Approach *(Dual Activity-Industry and Science Working Together)*

Scientific Development

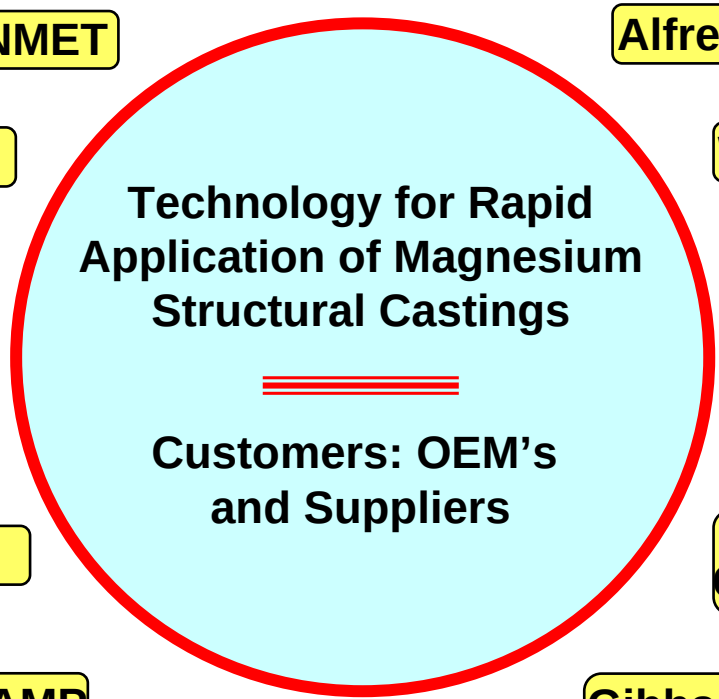


Demonstration Engine Cradle



Approach

Cooperative Resources



- Tech Transfer & LPPM Dev. — AFS
- Geo. Tech. — Material Characteristics
- Corrosion Mitigation & Bolt Load Retention — CANMET
- Alfred U. — Fracture Mechanics
- Material / Damage Simulation Model — SNL
- WMT&R — Material Testing & Database
- Casting Process Simulation — ORNL
- MSU — Material / Damage Simulation Model
- NDE Development — LLNL
- EKK, Inc — Process Modeling
- Funding — DOE
- Creative Concepts — Cost Model & Design Guide
- OEM Collaboration — USAMP
- Gibbs/Meridian & Hydro Mg — Casting & Alloy Development
- 34 Suppliers 3 OEM's

Technical Accomplishments & Results

- ❑ Completed magnesium cradle re-design and FEA analysis.
- ❑ Hundreds of prototype Cradle castings were produced with subsystem and full vehicle validation testing completed with no issues.
- ❑ The magnesium cradle achieved a 5.5 Kg reduction in weight (35%) with respect to the current aluminum cradle now used in production applications.
- ❑ Completed mechanical property and microstructural characterization of numerous magnesium alloy production components.
- ❑A new high temperature creep resistant alloy AE44 was developed by participating Hydro Magnesium team, which successfully completed bench and vehicle testing.
- ❑ CANMET's corrosion studies showed the need for dissimilar metal isolation requirements.
- ❑ Bolt Load Retention (BLR) CANMET analysis demonstrated that the Cradle attachments would meet vehicle performance requirements. BLR standard written for submission to SAE for committee approval.

Mg Cradle Castings

Tech. Accomplishments & Results (con't)

- ❑ SCMD team developed and implemented successful galvanic corrosion mitigation strategy which proved successful in bench and vehicle validation testing.
- ❑SCMD material testing was completed and information included in the Automotive Light Metal Material Database.
- ❑ Mississippi State University and Sandia National Lab successfully demonstrated their Multi-Scale material model.
- ❑ Lawrence Livermore National Lab completed fabrication of several ASTM E505 Radiographic Inspection Standards (RIS) and demonstrated the benefit of infrared temperature sensors.
- ❑ Project demonstration cradle passed all validation requirements with no issues and is in volume production on the 2006 Z06 Corvette.
- ❑ SCMD and MCPP Project Teams developed and published the *Magnesium 2020 Document* which outlines a North American Strategic Vision (from 2005 through the year 2020) for magnesium automotive usage.
- ❑ SCMD project Principal Investigators, OEMs and Suppliers published and presented a significant number of papers at various USCAR/USAMP, SAE. NADCA, TMS, DOE and IMA functions to date.

Technology Transfer

- ❑ SCMD final report (Aug. 29, 2006) was published and delivered to all project participants
- ❑ Transfer SCMD knowledge (and lessons learned) to Mg product teams
- ❑ Use the knowledge to develop lightweight components and sub-systems
- ❑ Continue to support Mg development activities

Lessons Learned

- Coatings (when damaged) can intensify galvanic corrosion
- Isolation between Mg and dissimilar materials such as steel is critical, minimum of 5mm separation is recommended.
- Aluminum 6061, 6063 and 5052 provide good isolation when correctly used.
- Wall thickness of HPDC components must be limited to 10mm maximum to ensure minimum shrinkage and gas voids.
- Improperly sealed joints can lead to significant galvanic corrosion. Threaded holes must be capped to create a seal or aluminum isolation sleeves must be used.
- Texturing of mold surfaces has a positive influence on casting surface by reducing mold flow lines, laps and cold shuts.
- Infrared optical temperature sensors proved to be accurate with a very rapid response time when compared to standard thermocouples.
- Computer modeling of mold fill and solidification proved to be a useful tool in guiding the design process.
- Use of the Mg cradle had a 12.4 lbs (35%) mass savings and component cost saving.

Relationship to FreedomCAR

"Enable the high volume production of vehicles that are: half the mass, are more recyclable, match or surpass quality & durability versus today's vehicles"

- **SCMD Project Team provided:**
  - **An Automotive Light Weight Material Database that will be applicable to all future Mg. Projects.**
  - **SCMD and MCPP Project Teams developed and published a Magnesium 2020 Document that outlines a North American Strategic Vision (from 2005 through the year 2020) for Automotive Weight Reduction using magnesium components.**
- **SCMD Project indicated the possibility of reducing vehicle mass by enabling use of light weight cast magnesium for highly loaded components through:**
  - **Lower Manufacturing Costs**
  - **Lower weight reduction of casting components. Mg is 35% lighter than aluminum, and 65% lighter than cast iron.**
  - **Improved Casting Quality Requiring Lower Porosity and New Casting Methods**
  - **Infrastructure Development**

Summary

2006 Corvette ZO6

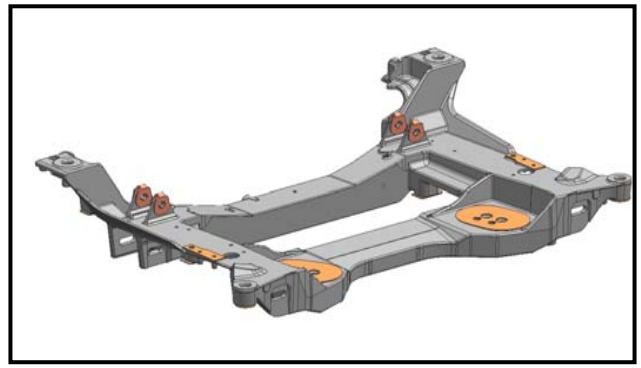
- The SCMD project accomplished its goals and went one significant step farther, the magnesium cradle went into production on the 2006 ZO6
- The Mg cradle helps the ZO6 achieve:
  - •50/50 weight balance
  - •0-60 times of 3.7 sec
  - •Fuel economy of 16 mpg city and 25 mpg hwy
  - •The ZO6 was the only vehicle to win GMs 2006 Chairman's Honor

Publications and Presentations

- **The publications and presentations made throughout the 66 month Project are too numerous to mention in this slide. For example:**
  - Approximately 315 presentations were made by SCMD Project Team Members and Principal Investigators at the: Quarterly Review Meetings; OEM Meetings; Chinese Magnesium Conference and Global Collaboration Conference at USCAR Office on 12/7/04, and at the yearly SAE World and AFSNADCA Congress Meetings from 2001 through 2006
- **The final SCMD Project report published on 8/29/06 has each PI's Technical report and a listing of all presentations and publications made throughout the 66 month period. They are typically listed as shown below.**
  - S. G. Lee, G. R. Patel, A. M. Gokhale, and Mike Evans, "Effects of Liquid Metal Gate Velocity on the Porosity in High-Pressure Die-Cast AM50 Alloy", *Magnesium Technology 2005 Symposium,* TMS Annual Meeting, San Francisco, CA, February 14-17, 2005.
  - A. Sreeranganathan, Soon Gi Lee, and A. M. Gokhale: "Quantitative Characterization of AM50 and AS21X Magnesium Alloys to Correlate the Variability in the Fracture Properties to Microstructure", *Automotive Alloys 2005 Symposium,* TMS Annual Meeting, San Francisco, CA, February 14-17, 2005.

AWARDS

The production model of the SCMD Project magnesium cradle has been recognized (world-wide) as noted below:



- **Winner of the North American Die Casting Association, 2006 International Die Casting Competition for best magnesium casting over 0.5 lbs.**
- **Winner of the International Magnesium Association Award for Excellence, for best application of magnesium in 2005**
- **Winner of Honorable Mention in the 2006 Automotive News PACE (Premier Automotive Suppliers' Contribution to Excellence) award for product innovation.**
- **Scholastic Recognition; Soon Gi Lee,(a Graduate student of Professor Gokhale at Georgia Institute of Technology) was selected as the 2006 Magnesium Best Student Paper Award Recipient. The award is sponsored by The Metallurgical Society (TMS) Magnesium Committee and honors an outstanding technical presentation by a college student in the field of Mg Technology.**

Thank You

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Questions?

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