Ultra Large Castings
For Lightweight Vehicle Structures
Project ID lm_18_quinn
AMD 406

2009 DOE Merit Review Presentation

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Presented by: James Quinn, General Motors

Acknowledgement

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Overview

Timeline

- Start May 12, 2004
- Finish March 31, 2009
- 95% Complete

Budget

- Total project funding
  - DOE share: $1,196K
  - USAMP share: $1,310K
- Funding received in FY08
  - $149.4 K
- Funding for FY09: $17.9 K
- Funding for FY10: $0K (Project ends FY09)

Barriers addressed

- 50% Weight Reduction
- Affordability

Partners

MAGNA COSMA INTERNATIONAL

MAGNA G-MAG INTERNATIONAL INC.

Aar-Kel Moulds Ltd.

HUSKY

HITACHI Inspire the Next

DSM

WMT&R

EKK

Project Lead:
Mike Maj
Ford Motor Company (Retired)

Objectives

Overall Objectives…

1. **Demonstrate that large, light metal castings can be used in place of conventional multi-piece stamped and welded steel automotive body structures to enable lightweight vehicle structures and systems that meet the Technology-Specific Research Goals for "Materials" as stated in the FreedomCAR and Fuel Partnership Materials Technology Roadmap. (50% mass reduction/affordable/recyclable)**
2. **Evaluate alternative manufacturing processes to the High Pressure Die Casting process for their potential to enable the production of aluminum and magnesium primary automotive cast structural components with consistent and predictable mechanical properties.**
3. **Demonstrate a "real world" application of a cast primary automotive structural component which embodies the geometric elements and manufacturing challenges that would be encountered in a much larger casting. (The chosen application is the Ford F-150 Front End Structure, aka Shotgun.)**

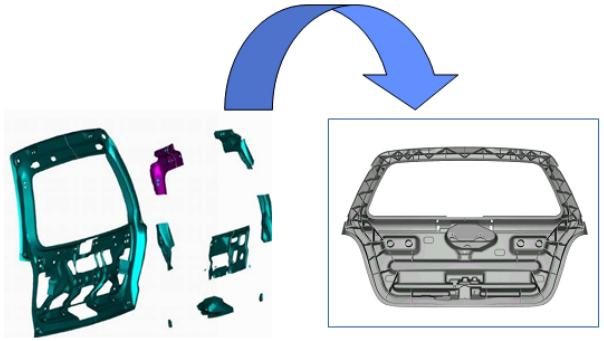
2008 - 2009 Objectives…

- **Evaluate the mechanical properties of Thixomolded magnesium parts manufactured after mold design changes and casting process optimization.**
- **Close out project and complete documentation.**

USAMP AMD406– Ultra Large Castings

Technical Accomplishments/Progress/Results

Substantiate Rationale…



Conventional Multi-piece Stamped/Welded Design

One-piece Integrated Casting

Reduce Cost by Integrating Components

Reduce Weight by Eliminating Structural Redundancy and using Lighter Material (Mag or Al)

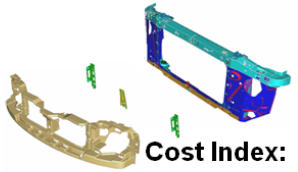
Assumption

System Level Cost and Weight Comparison

Cast Magnesium Radiator Support (2006 MY F-150)

Cost Index: .78
Total Weight: 14 lbs.

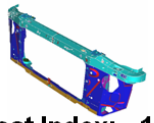
Conventional Stamped Steel Radiator Support With SMC GOR (2006 MY Expedition)



Cost Index: 1.00
Total Weight: 42 lbs

Structural Level Cost and Weight Comparison

Cost Index: .90
Tooling Cost Index: .25
Total Weight: 10.5 lbs.



Cost Index: 1.00
Tooling Cost Index: 1.00
Total Weight: 26 lbs

Rationale for Ultra Large Castings:

- At System Level, Cast Mg Design is 22% Lower Cost and 67% Lower Weight
- At Structural Component Level, Cast Mg is 10% Lower Cost and 60% Lower Weight
- Tooling for Castings 75% Lower Cost than Stamping

Case Study

A case study of the F-150 Magnesium Radiator Support validates the assumption that ULCs reduce weight and cost.

Identify Limitations of HPDC…

Cold Chamber High Pressure Die Casting (HPDC) has evolved into the preferred high volume casting process for the industry due to familiarity and simplicity.

The nature of the HPDC process, equipment and practices results in castings with high levels of porosity.

Porosity has a negative effect on mechanical properties. As porosity levels increase, strength and ductility decrease.

Most primary automotive structural parts require ductility levels and consistency of mechanical properties beyond the capabilities of HPDC.

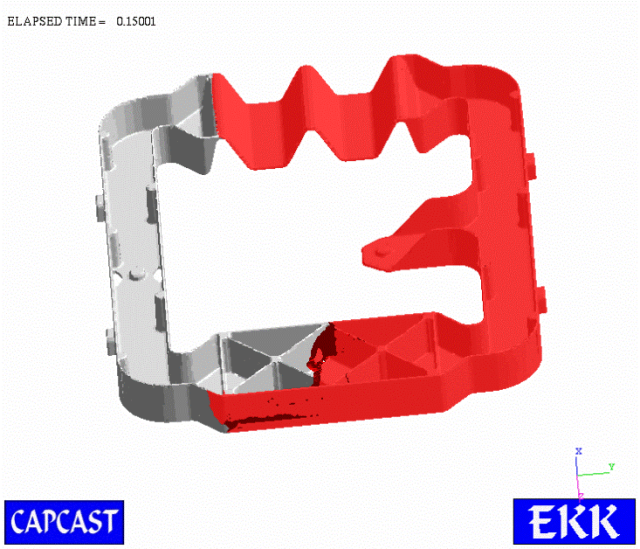
Explore New Processes...

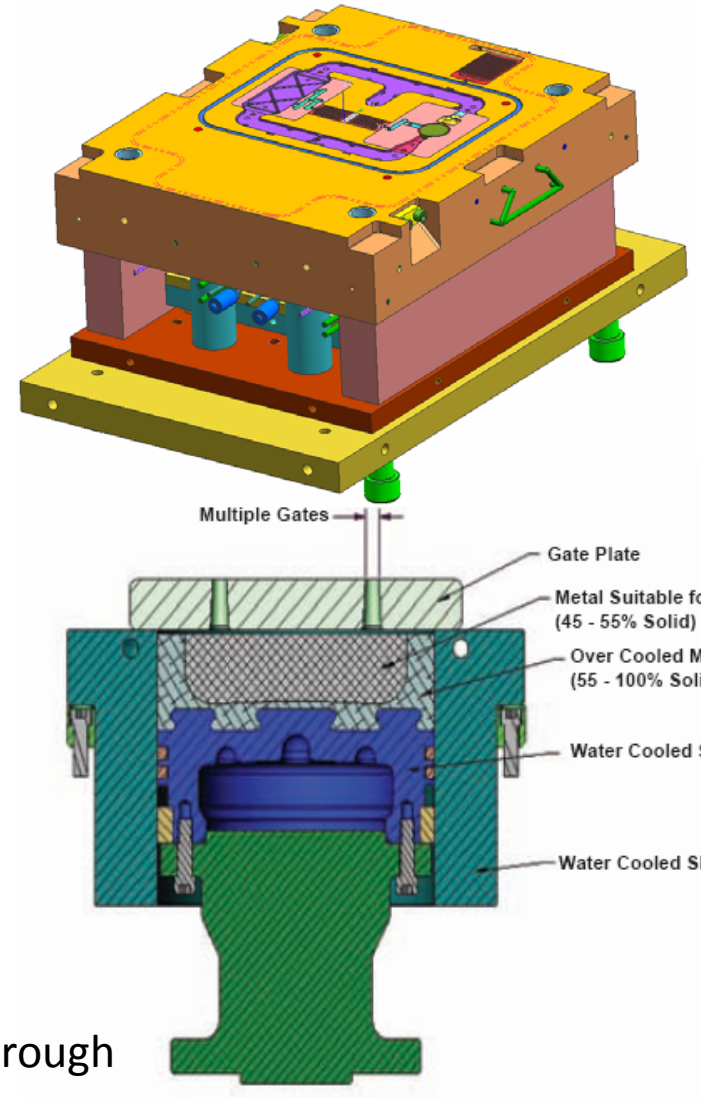
The ULC project is exploring emerging casting processes that have prospects of overcoming the drawbacks of HPDC through the use of **Semi-solid molding** and/or **multi-port hot runner technology** such as:

Sub-Liquidus Casting (SLC)
- **Aluminum**
- **Magnesium**

Thixomolding
- **Magnesium**

These Processes have thin-wall capability with high potential for improved ductility and uniform mechanical properties.

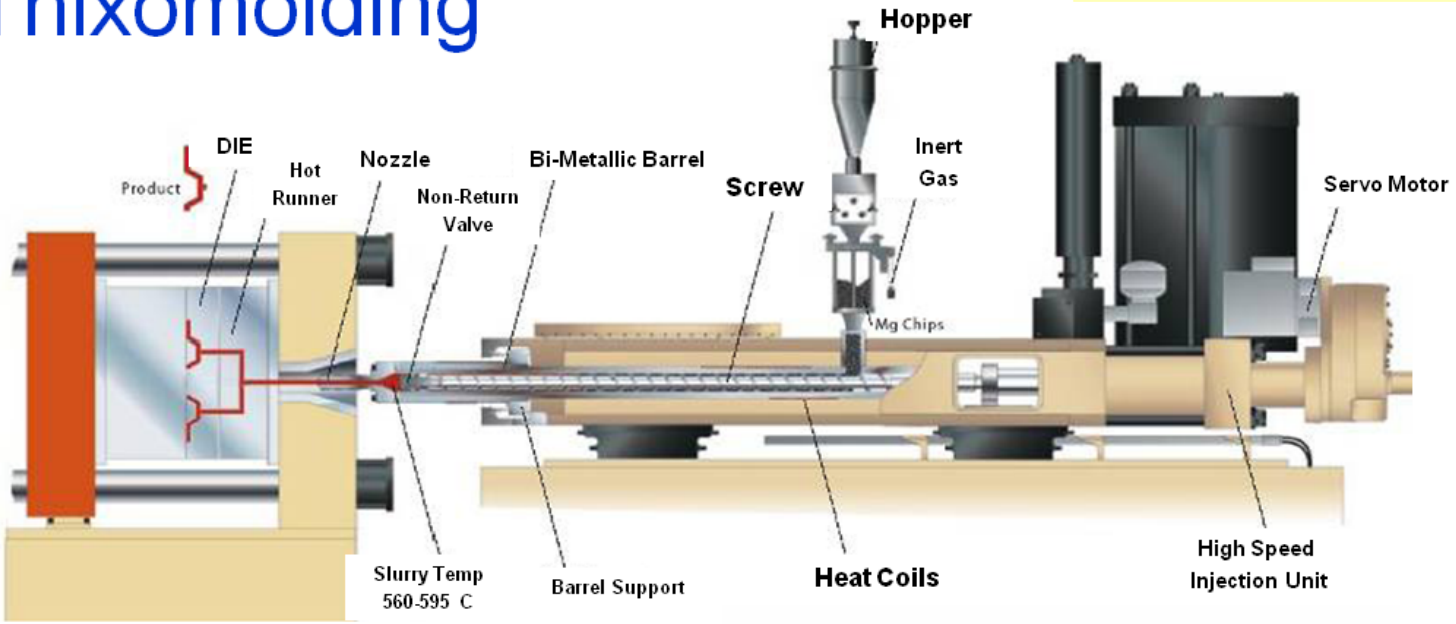


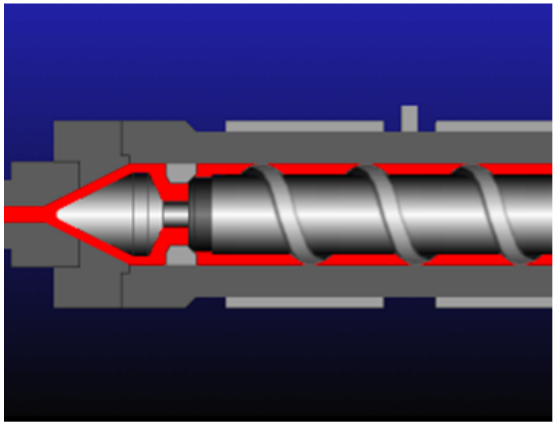


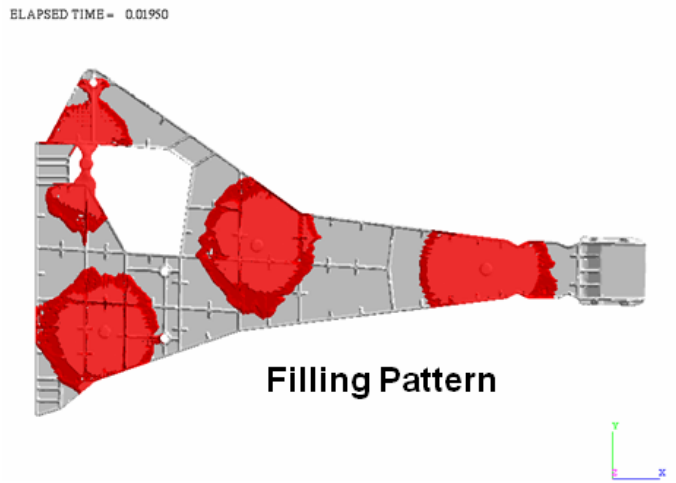
SLC Process

Shot Cylinder is under die in a vertical Orientation and injects semi-solid metal through One or more openings in a gate plate.

Thixomolding



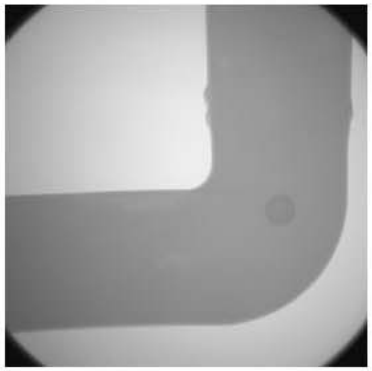




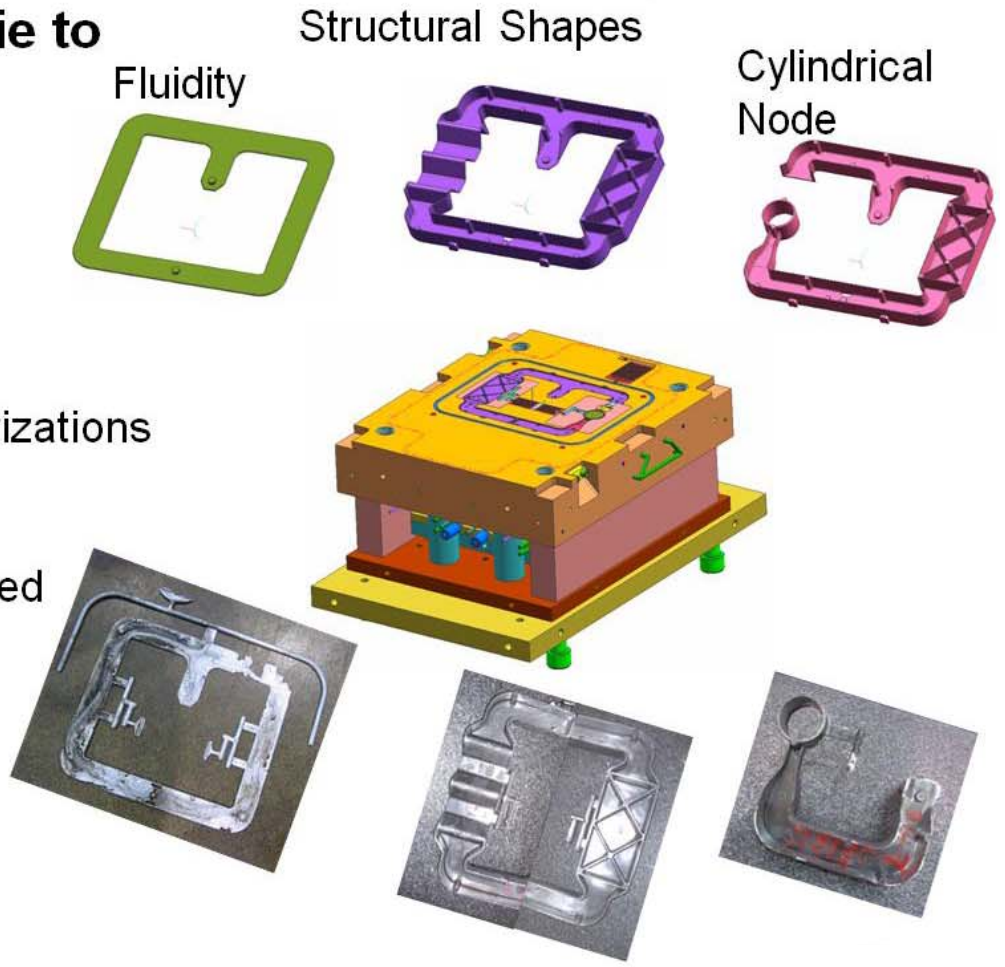
Technical Accomplishments/Progress/Results

Designed and fabricated reconfigurable"Test Part" die to evaluate SLC Process.

- Conducted Design of Experiments
- Evaluating Part Quality
  - NDE Methods (X-Ray)
  - Mechanical Property Characterizations (TYE at WMT&R)
- Aluminum and Magnesium Evaluated



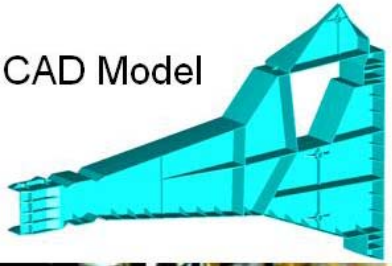
SLC Test Part Configurations



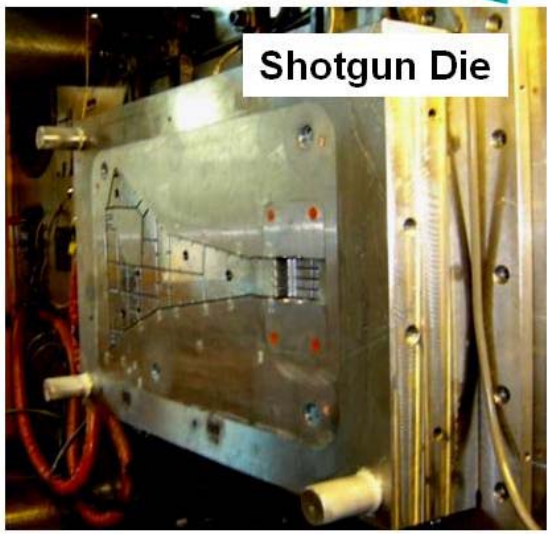
Technical Accomplishments/Progress/Results

Thixomolding Process:

Designed "Shotgun" using Flow & Solidification simulation software



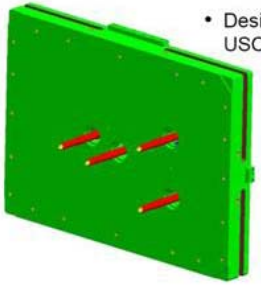
Designed and Fabricated Tool



Incorporated Industry-first Multi-drop Asymetrical Hot Runner

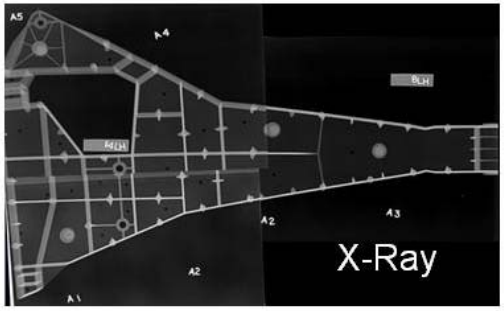
Four Drop, Non-Symmetrical Hot Runner

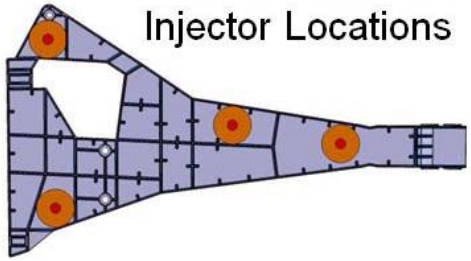
- Designed specifically for USCAR project



3 Casting Trials for DOEs

Evaluated part quality and process capability



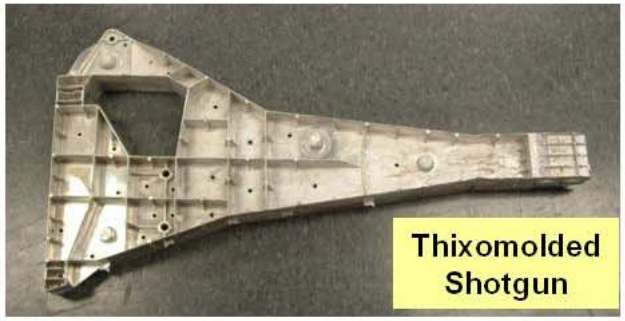


Technical Accomplishments/Progress/Results

"Real World" Demonstration (Shotgun)

- Fabricated 3 Ford F-150 complete Body-in-Whites with all-magnesium front end structures consisting of ULCs for use as design aid and 4-poster durability fatigue tests.
- Durability of the all-mag front end structure (consisting of 3 large Mg castings) is equivalent to or better than conventional stamped steel construction.
- Component level and system level test results show good correlation with modeling.
- Established a "Quality Rating" using X-Ray image as the basis for an acceptance criterion other than visual inspection.
- Implemented changes to part design, tooling, and process parameters to improve the mechanical properties of the shotgun.
  - E.g., changes were made to the tooling to add more overflows to push air out of the part; reduced the volume of the part so that we were not at the casting machine's limits.

"Real World" Demonstration...



Demonstrate that the process knowledge gained can be applied to real-world vehicle light-weighting.

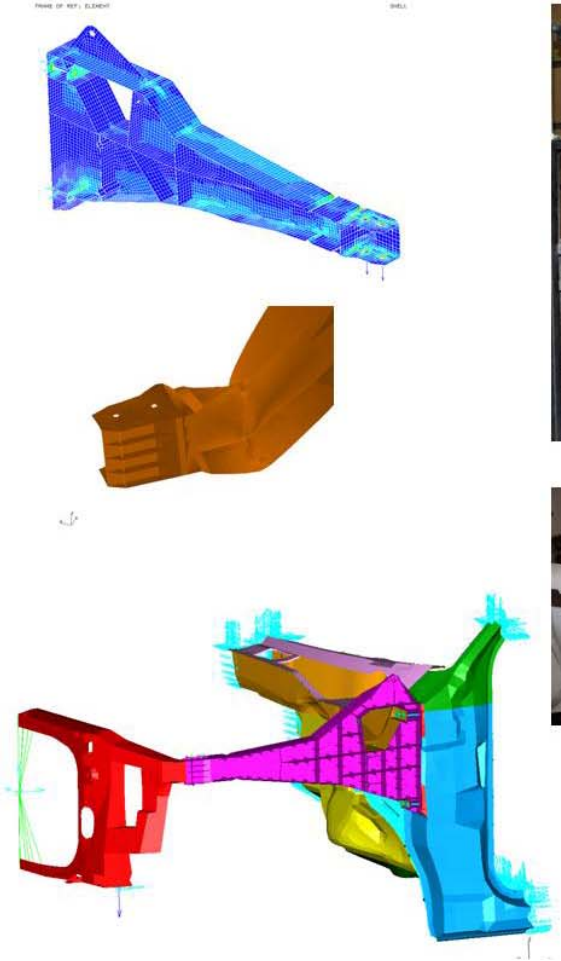
3 ULCs replace a conventional multi-piece steel and plastic front end structure for a 67% weight savings.

69 lbs.→ 22 lbs.

Technical Accomplishments/Progress/Results

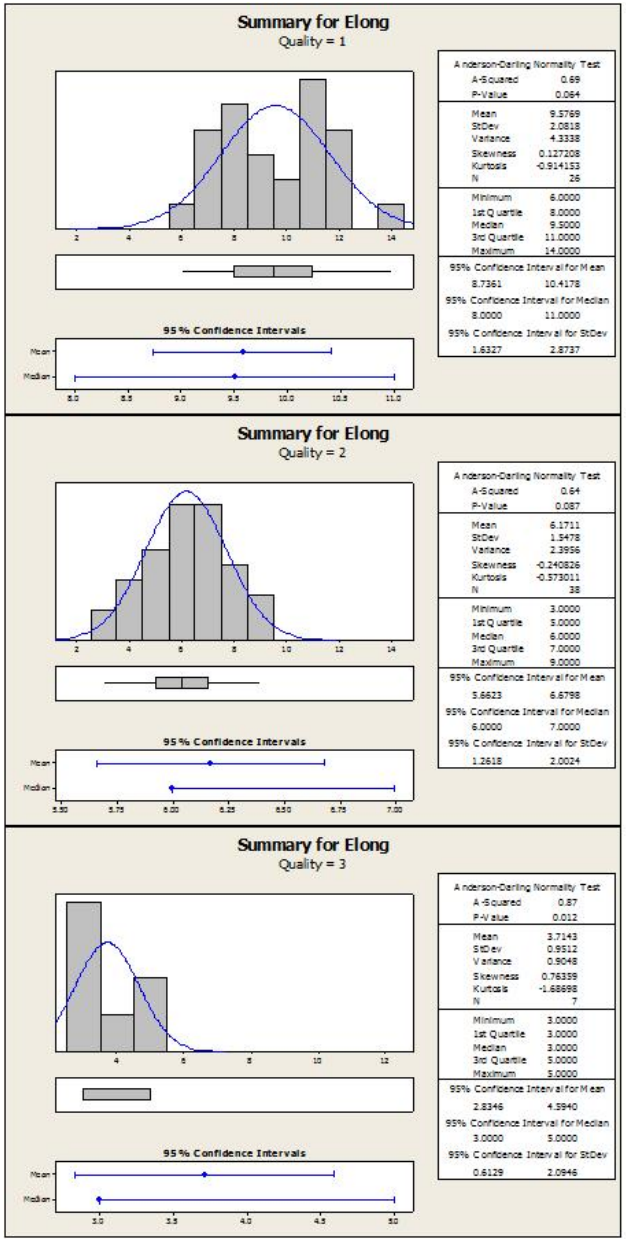
"Real World" Demonstration (Shotgun)

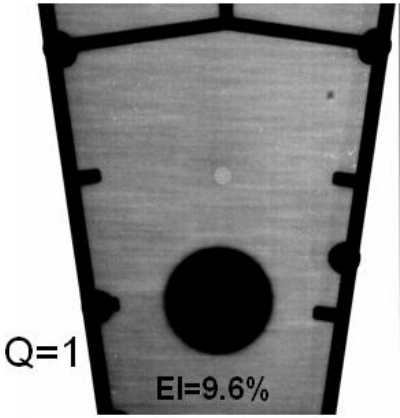
Design and analysis

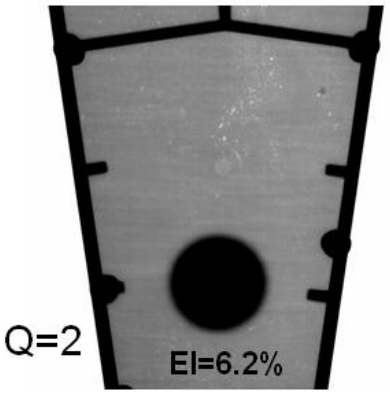


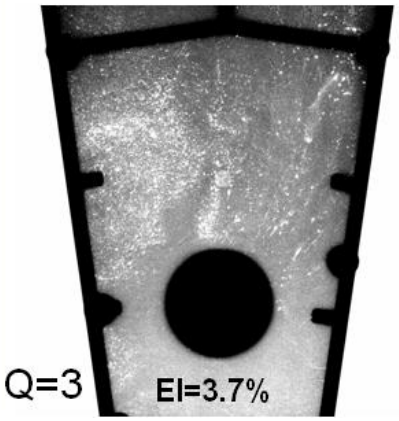
Component Testing

System Testing

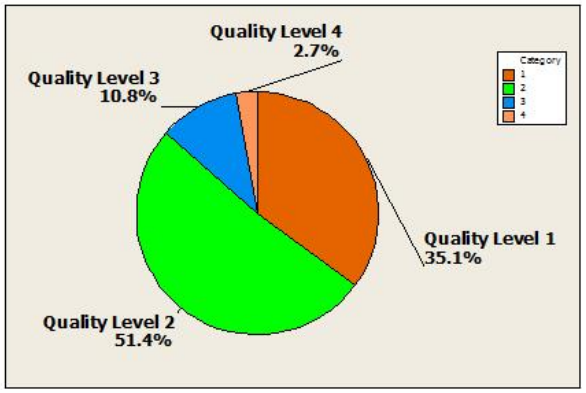








Specifying the acceptance criterion "**X-Ray image Quality Level must equal 1**" in a certain critical region of the shotgun allows the tensile test data to be sorted as shown on the left. The mean elongation of acceptable parts is near the 10% target.



Technical Accomplishments/Progress/Results

Tensile Test Results
AM60-B Magnesium

	UTS	YS	El %
Thixomolded Shotgun (Q=1)	233	121	9.57
HPDC Door (Ford study)	196	123	5.68

Future Work

- Complete evaluation of the mechanical properties of Thixomolded magnesium parts manufactured after mold design changes and casting process optimization.
- Close out project and complete documentation.
  - The Ultra Large Casting Project is officially ended on March 31, 2009

Summary

- A rationale is established for substituting ULCs in place of stamped steel automotive structures.
- A case study indicates ULCs are Cost Competitive with stamped steel structures.
- HPDC is the process of choice for producing large castings. The mechanical properties achievable with HPDC are not suitable for most primary structural components
- New casting processes such as SLC and Thixomolding were evaluated and appear to provide improved mechanical properties, but the processes must be optimized and scaled-up.
- The lightweighting potential of ULCs is highlighted by a “real world” application demonstration which has been analyzed and tested.
- The Thixomolded magnesium shotgun provides evidence that it is possible to produce cast parts of acceptable quality with mechanical properties and ductility levels that meet the requirements for primary structure. This supports the FreedomCAR target of 50% weight reduction.