Ultra Large Castings for Lightweight Vehicle Structures – AMD 406

USAMP
2008 DOE Peer Review Presentation
February 28, 2008

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•This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Number DE-FC26-02OR22910.

Purpose of Work

Describe and substantiate a rationale for using large light metal castings in place of conventional stamped and welded steel automotive body structures to reduce vehicle weight. Improve the quality of cast components and provide a "real-world" application demonstration.

Improve the Quality of cast components

- Process selection and Capability analysis
  - Achieve homogeneous distribution of properties
  - Demonstrate consistent and predictable mechanical properties
  - Demonstrate Improved strength and ductility

Application Demonstration

- Design, analyze and test a vehicle component
  - Demonstrate a mass reduction of 40% - 60%
  - Show potential for competitive cost compared to conventional steel construction.
  - Demonstrate parts consolidation,
  - Show potential for reduced investment cost in tooling and dies
  - Demonstrate improved energy absorption.

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Barriers

- Process Technical Barriers
  - High Pressure Die-casting (HPDC) is the only affordable high volume casting process capable of producing large, thin-walled aluminum or magnesium castings.* HPDCs are not suitable for most primary automotive body structural applications, especially those required to absorb large amounts of crash energy.
  - Further application of affordable ultra-large structural castings are limited by the mechanical properties achievable with conventional HPDC.
  - Emerging high-integrity semi-solid casting processes exhibit thin-wall capability with high potential for improved ductility and uniform mechanical properties vs. HPDC, but equipment needs to scaled up to produce large automotive components.

- Application Technical Barriers
  - Automotive Industry infrastructure and processes are biased toward stamped steel designs.
  - Lack of Design Guidelines for ULCs
  - Limited knowledge base for modeling and validating structural castings.
  - Incomplete material property database.
  - Fastening and Joining issues for combinations of Mg, Al & steel
  - Corrosion prevention in mixed material designs

**Refer to back-up slide to address questions on this statement*

Approach

- Substantiate Rationale for Ultra Large Castings (ULCs)
- Identify Inhibitors to wider use of ULCs
- Explore new manufacturing processes capable of producing castings with better mechanical properties
- Demonstrate a “real world” application of ULC.

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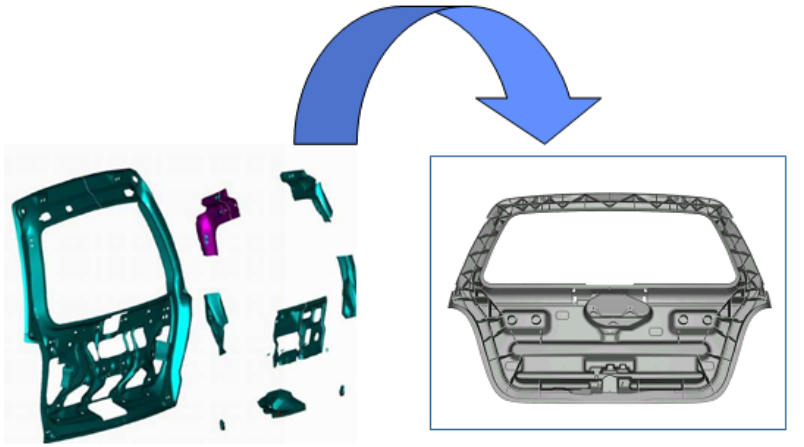
Approach: Substantiate Rationale…



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)**

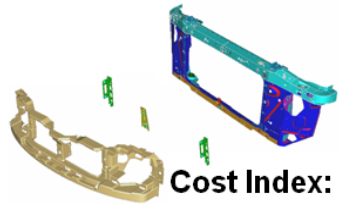
Assumption

System Level Cost and Weight Comparison

Cast Magnesium Radiator Support (2006 MY F-150)

Cost Index: .78
Total Weight: 14 lbs.

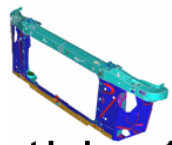
Conventional Stamped Steel Radiator Support With SMC GOR (2006 MY Expedition)



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.

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Approach: Identify Inhibitors…

• 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 the entrapment of air which causes 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 beyond the capabilities of HPDC.

Approach: 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.

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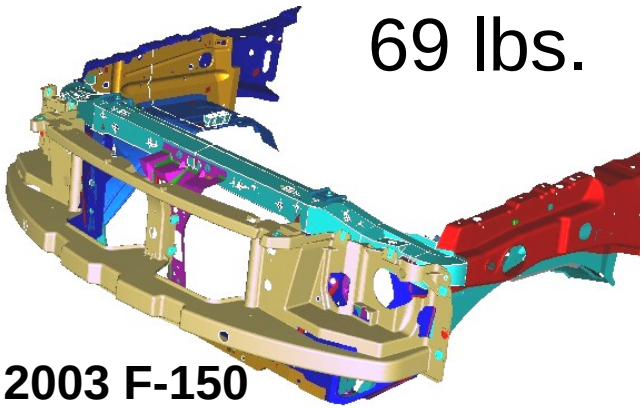
Approach: "Real World" Demonstration...

Replace steel inner fender structure with Cast Magnesium

Conventional Steel with Plastic GOR

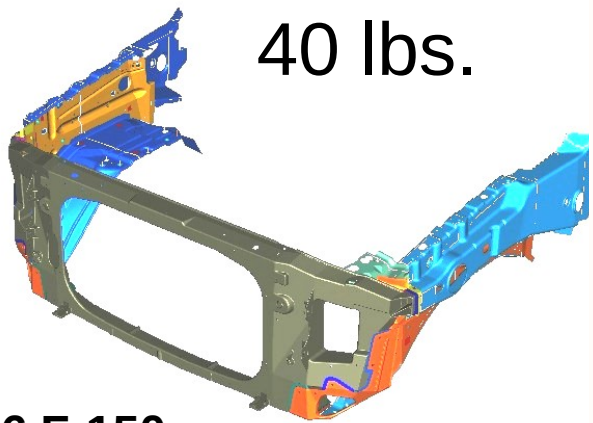
69 lbs.



2003 F-150
2005 Expedition

Conventional Steel with Cast Mag Radiator Supt.

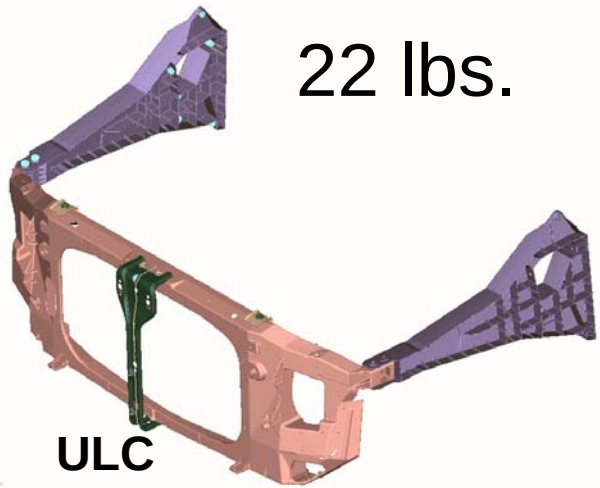
40 lbs.



2006 F-150

Thixomolded Mag Shotguns with Cast Radiator Support

22 lbs.



ULC

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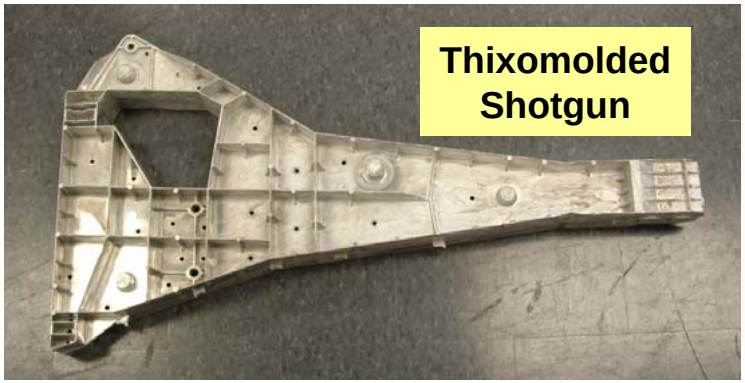
Approach: "Real World" Demonstration...



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

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

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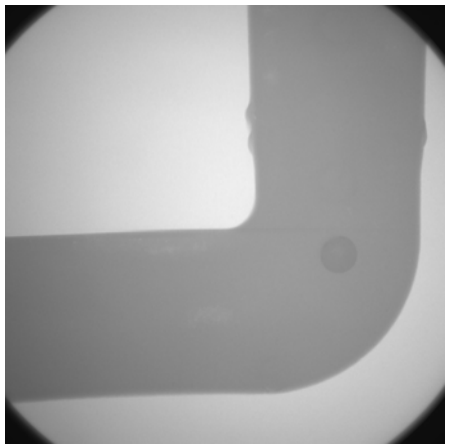
Accomplishments/ Progress/Results - SLC Process

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

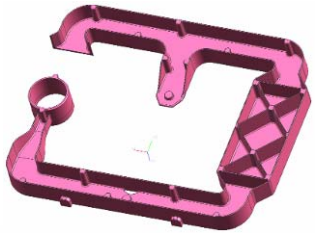


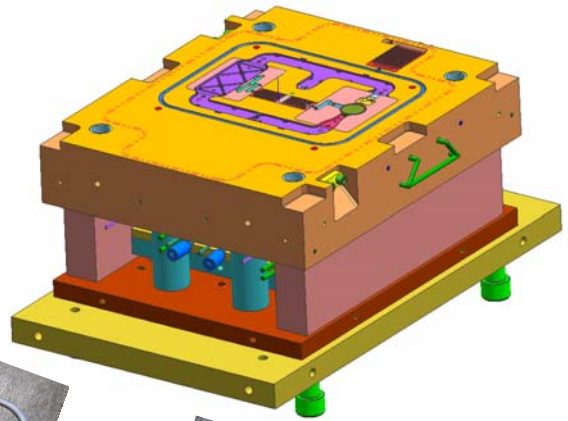
SLC Test Part Configurations

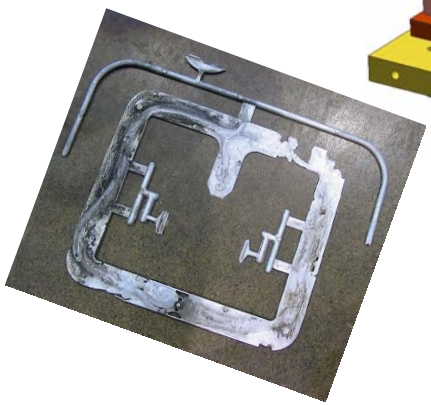
Fluidity

Structural Shapes

Cylindrical Node







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Accomplishments/Progress/Results Thixomolding Process

Designed “Shotgun” using Flow & Solidification simulation software

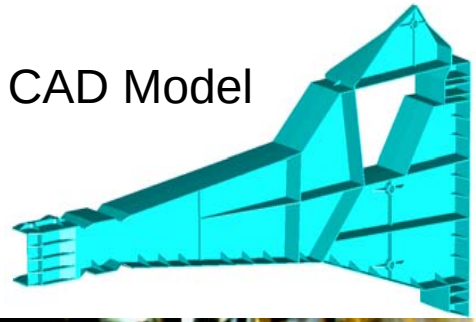
Designed and Fabricated Tool

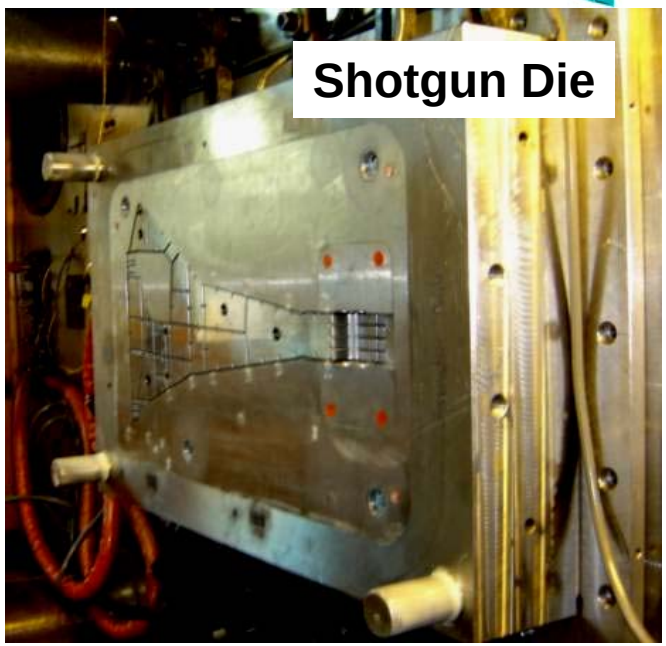
Incorporated Industry-first Multi-drop Asymetrical Hot Runner

3 Casting Trials for DOEs

Evaluated part quality and process capability

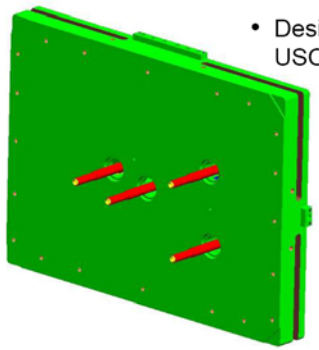
CAD Model

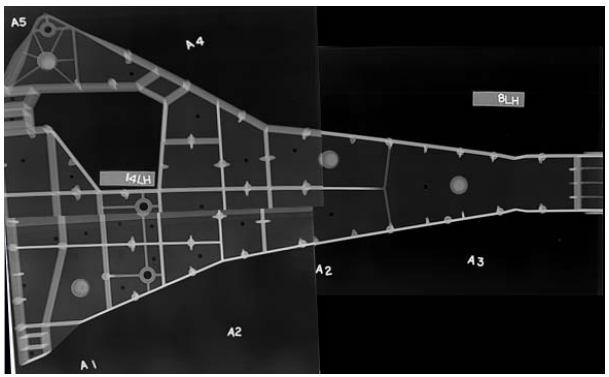




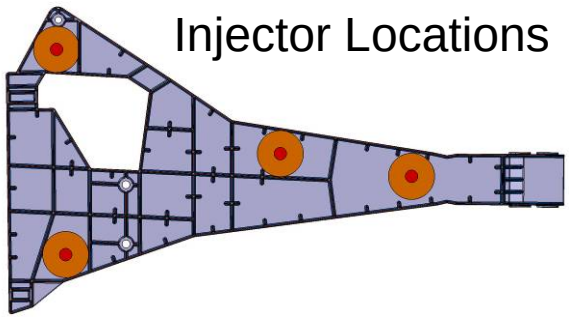
Four Drop, Non-Symmetrical Hot Runner

- Designed specifically for USCAR project





Injector Locations



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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.

FEA conducted for static durability and crash.

Conducted component level and system level testing

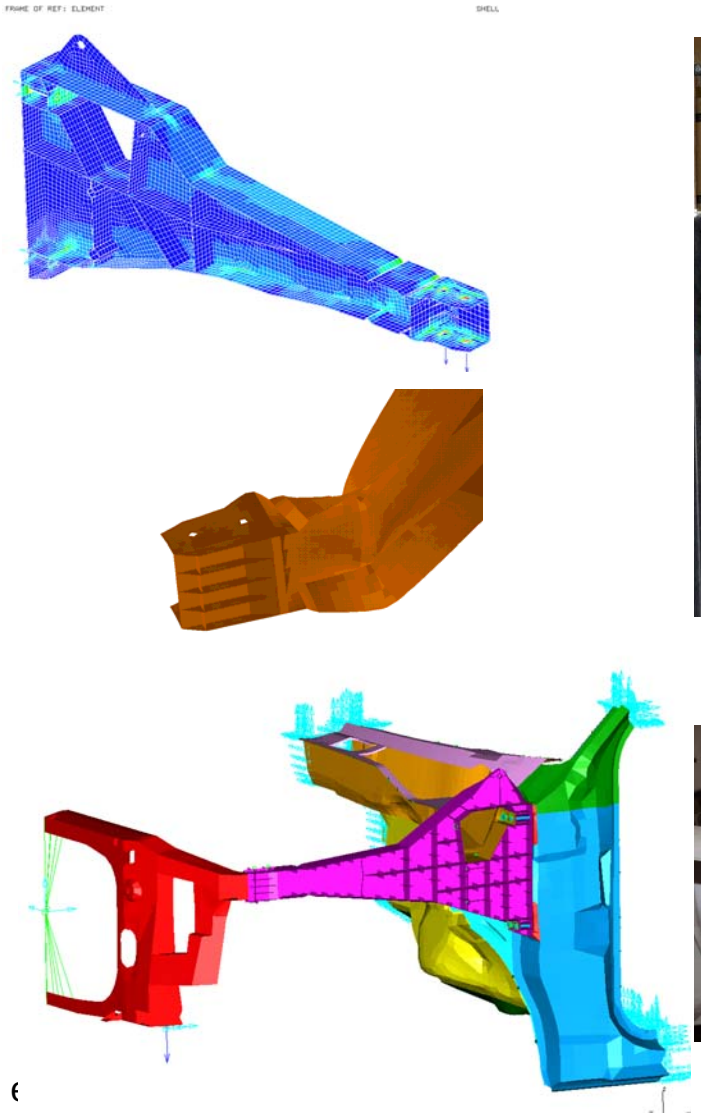
Comments on Test Results:

Even though targeted minimum elongation values of 10% were not achieved in the thixomolding process, tested parts still exhibited plastic deformation before failure.

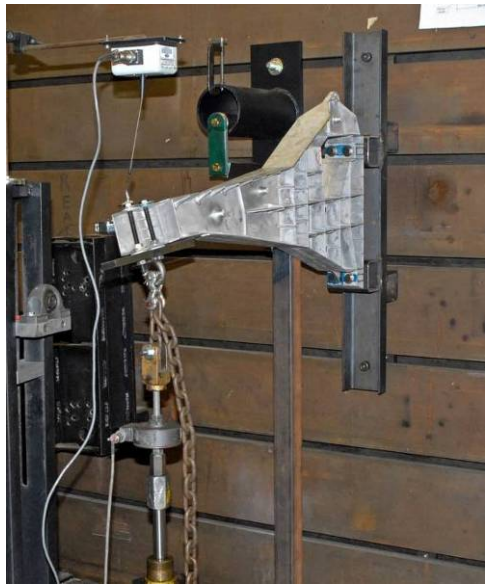
Durability of the all-mag front end structure is equivalent to or better than conventional stamped steel construction.

Accomplishments/Progress/Results "Real World" Demonstration (Shotgun)

Design and analysis



Component Testing



System Testing

Technology Transfer and Activities for Next Fiscal Year

A complete report will be furnished to Ford, GM and Chrysler.

Technical Papers will be submitted to various organizations such as TMS, IMA, SAE, etc.

This project will end in Q3 FY2008.

Publications, Presentations, Patents

Michael Maj, Ultra Large Castings for Lightweight Vehicle Structures, IMA Automotive Seminar, March 28, 2007, Laurel Park Manor, Livonia, MI

Michael Maj, Ultra Large Castings for Lightweight Vehicle Structures, TMS 2007 Annual Meeting, 2/21 thru 3/1, Orlando, FL

IMA Award of Excellence: Ultra Large Casting (USCAR) “Shotgun” awarded 1st Place in the Process Category, IMA 2007 Awards Competition, May 15, 2007 Vancouver, BC

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 they need to scaled-up.
- The lightweighting potential of ULCs is highlighted by a “real world” application demonstration which has been analyzed and tested.

Competing Approaches

Example:

The Audi A8 uses 36 large, thin walled aluminum die castings in its Body structure. These are made with a premium Alcoa Vacuum Die Cast Process and they are:

***Expensive*. Typically, parts cost 2 to 3 times more than the processes ULC is investigating.**

***T6 Solution Heat Treating* is required.**

Heat treat causes distortion with *added cost for straightening*

The ULC project focus is on assessing the capability of simple, lower-cost casting processes yielding parts with required properties that can be used as-cast or with a T5 artificial aging.