SHILOH®

Lightweighting without compromise.™

High Pressure *Casting for Structural Requirements*

HPC - September 6, 2017

HJG_8_12_17

Shiloh Vision & Mission

VISION:

We believe in creating innovative solutions for sustainable mobility and a safer, healthier environment.

MISSION:

We will consistently deliver value-creating, sustainable lightweighting solutions through team excellence and world-class customer service to the global transportation community.

Shiloh's Place in the Market

Lightweighting without compromise.®

Shiloh value proposition

- ✓ Reduce weight
- ✓ Reduce complexity
- ✓ Reduce emissions
- ✓ Reduce overall cost
- ✓ Reduce fuel consumption

Shiloh products meet industry need for lightweight components

Product Focus

Vehicle structures and optimized material products

	Product system	Products	Associated components
Body	• **Closures** • **Interiors** • **Structures**	• Body & dash panels • Cross car beams • Door inners • Lift gates • Seating structures	• Body panels • Floor panel assemblies • Rear cross members and braces • Seat pans and backs • Tunnel assemblies
Chassis	• **Driveline** • **Frame & Suspension**	• Axle housings • Cross-members • Frame rails • Links & nodes • Shock towers	• Axle covers • Frame nodes • Front end carriers
Propulsion	• **Engine** • **Transmission** • **Electrification**	• Crank case reservoir systems • Housings • Gears, planetary carriers • Pans & covers	• Bell housings • Electric axle drive cases • Engine covers • Oil filtration modules • Power distribution modules • Transmission covers

- *Customer collaboration on vehicle systems to achieve optimized lightweight products*
- *Shiloh's unique multi-material solutions provide maximum value*
- *Global manufacturing to accommodate product requirements*

Focus on products for vehicles without compromising safety, performance, weight, cost

Global Scale

Manufacturing footprint

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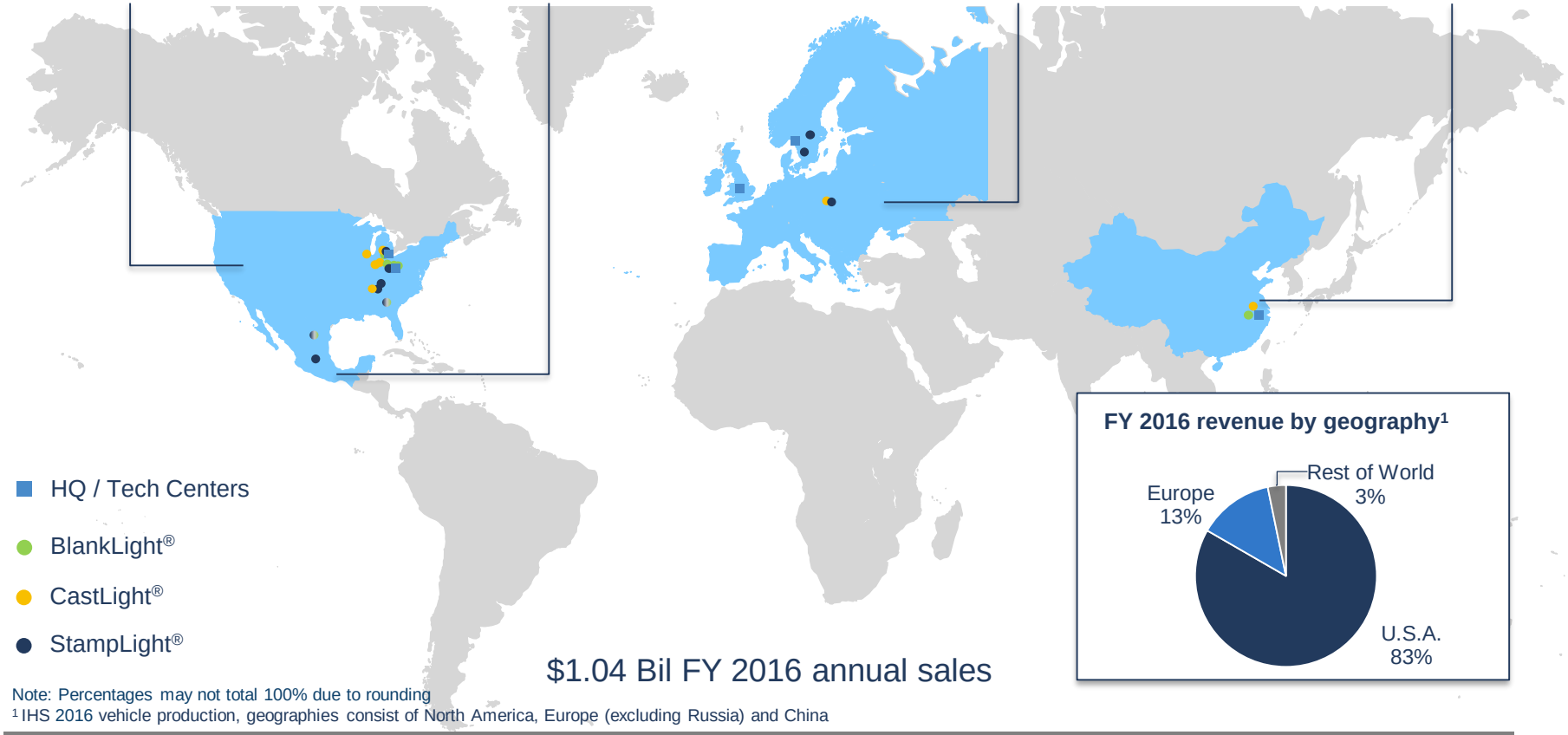
U.S.	Mexico	Europe	China
• 17 facilities • 2 technical centers • 15 manufacturing facilities	• 2 facilities • 2 manufacturing facilities	• 6 facilities • 2 technical centers • 4 manufacturing facilities	• 3 facilities • 1 technical center • 2 manufacturing facilities

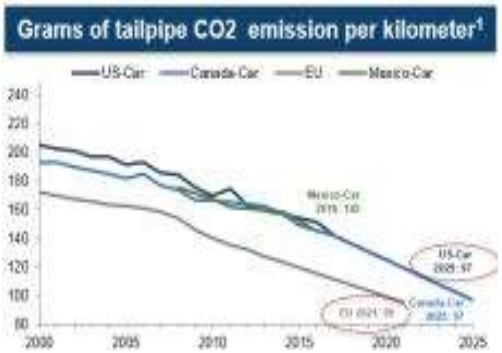


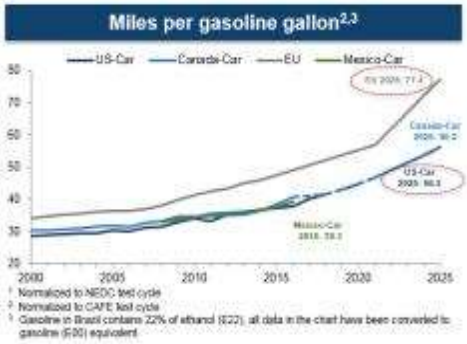
$1.04 Bil FY 2016 annual sales

Note: Percentages may not total 100% due to rounding
[1] IHS 2016 vehicle production, geographies consist of North America, Europe (excluding Russia) and China

Present in geographies comprising ~70% of global automotive production[1]

Transportation in our Global World





Satisfy demand for cleaner and safer mobility

- New vehicle technology to match mobility mega trends
  - Population shift from rural to urban, global increase in number of mega-cities
  - Governmental regulation
    - Demand for reduced emissions and improved fuel economy
  - Enhanced safety
  - Autonomous driving
  - Electrification
  - Car sharing

Technology Challenge to accomplish more with less material

Source: Synovate Survey & Ducker Analysis; International Council on Clean Transportation

Global Vehicles

Engineering and Materials

- **New engineering moment**
  - Expect more from components using less material
  - Lightweight, stiff, ductile, strong, with less over-design
  - Consistency, narrow capability bands
  - Pricing for structural components as normal commodities

- **Lightweighting strengthens in the core areas of the vehicle**
  - Propulsion, Drivetrain, Suspension, Steering
  - New materials and processes shift existing solutions

- **Many materials considered**
  - Steels compete vigorously (MS, AHSS, and new Gen 3 steels)
  - Aluminum and Magnesium (sheet and casting)
  - Carbon fiber, specialty plastics, and emerging composites

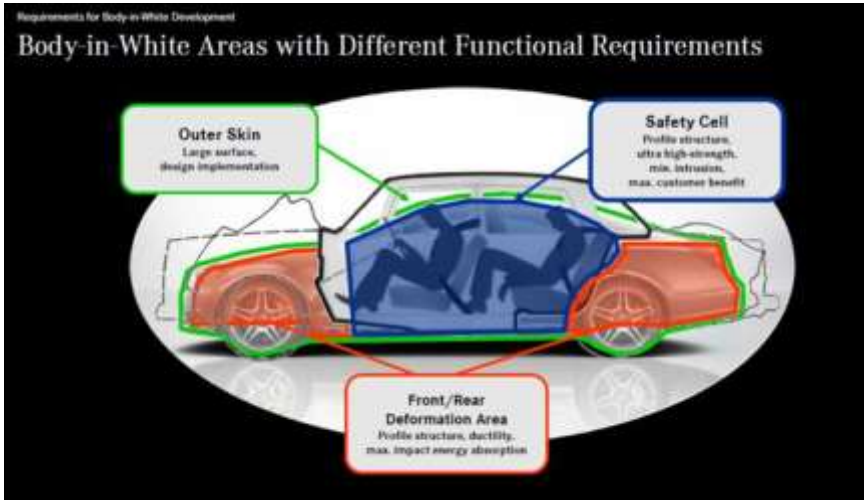
Displaced Older Design Trends

- **Framing (BIW) and body panels new growth area for lightweighting**

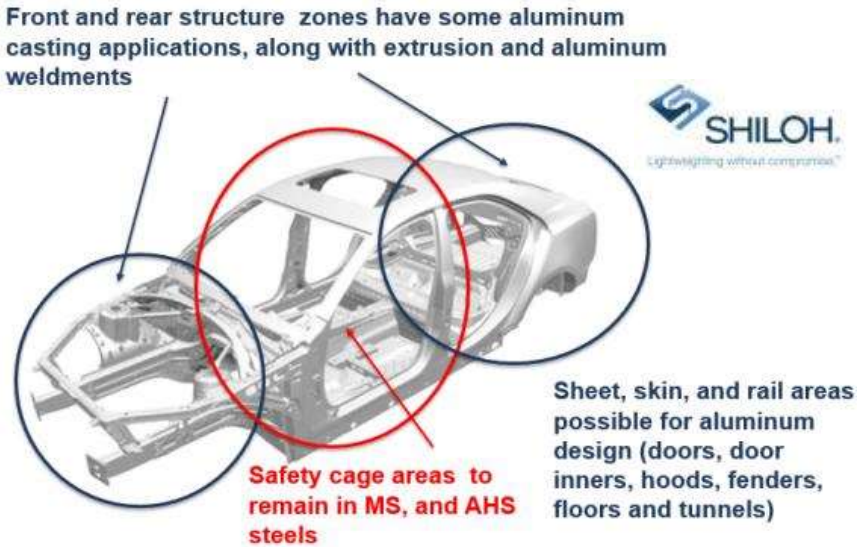
- **Traditional materials still have a strong base (Steel is still primary)**
  - Better development by large steel producers
  - New offers to increase properties with less mass
  - Simulation and CAE is well developed
  - Validation data is broad and well accepted (low risk)

- **Must be a compelling reason(s) to violate the norms**
  - Total cost, weight/mass
  - Multi-part consolidation with ease of joining
  - Platform and Plant level support for the innovation necessary

Mixed Material Vehicles –
BIW & Shell



Courtesy of Mercedes Benz 2017



New Materials can only be used in Body-in-White if the behavior can be predicted in simulation

The current design thinking is better reflected here

Safety Cage Zone
Front and Rear structures

Global HPDC

- **New requirements necessary for HPDC in these vehicle systems**
  - Focused growth
  - Applications replacing forgings, ferrous castings, stamping, weldments (BIW, Suspension, Steering applications)

- **Consistent, homogenous structures used in load path areas**
  - Frames, crash and strength relevant areas => lighter vehicles
  - Migrating to other concepts to reduce mass

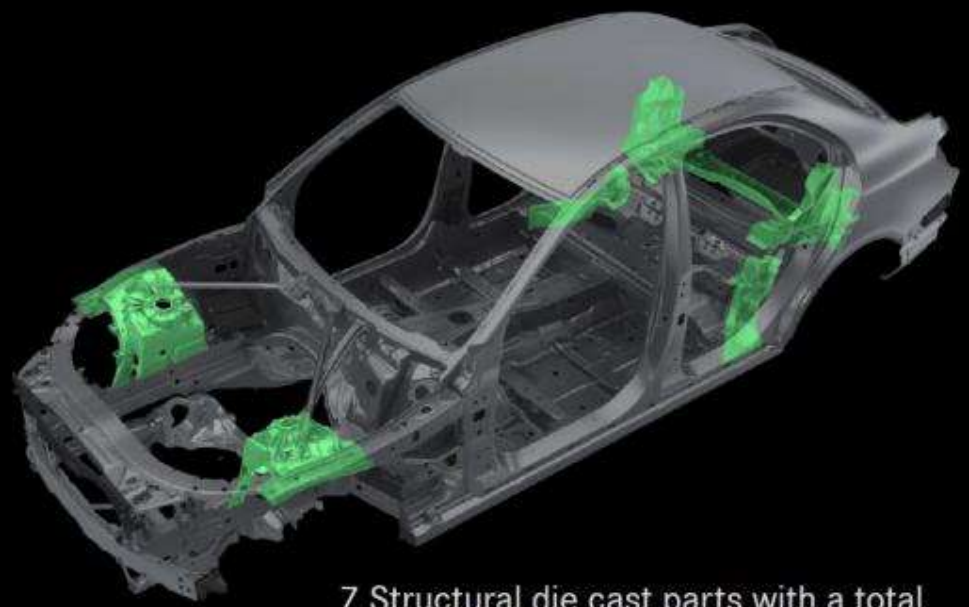
- ***Automotive sector is leading, the other product groups follow***
  - *Motorcycles, commercial vehicles, lawn and garden, small engine, recreational vehicles, eventually aerospace*

Industrialization shift for HPDC, and an ongoing challenge for new alloys and other materials

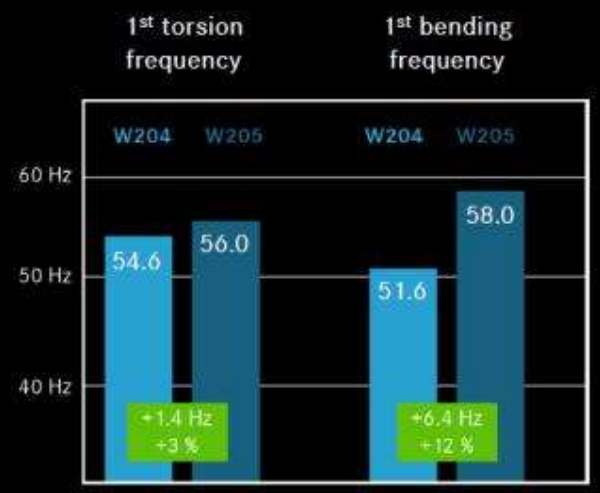
Material Usage Trends –
Structural BIW Current applications

Examples of Lightweight Design Applications

Structural Die Cast Parts in C-Class Body-in-White



7 Structural die cast parts with a total weight of over 19 kg/car.



The dynamic body rigidity is improved by approximately 1.5 Hz due to the use of diecast aluminium in the structure

Mercedes-Benz

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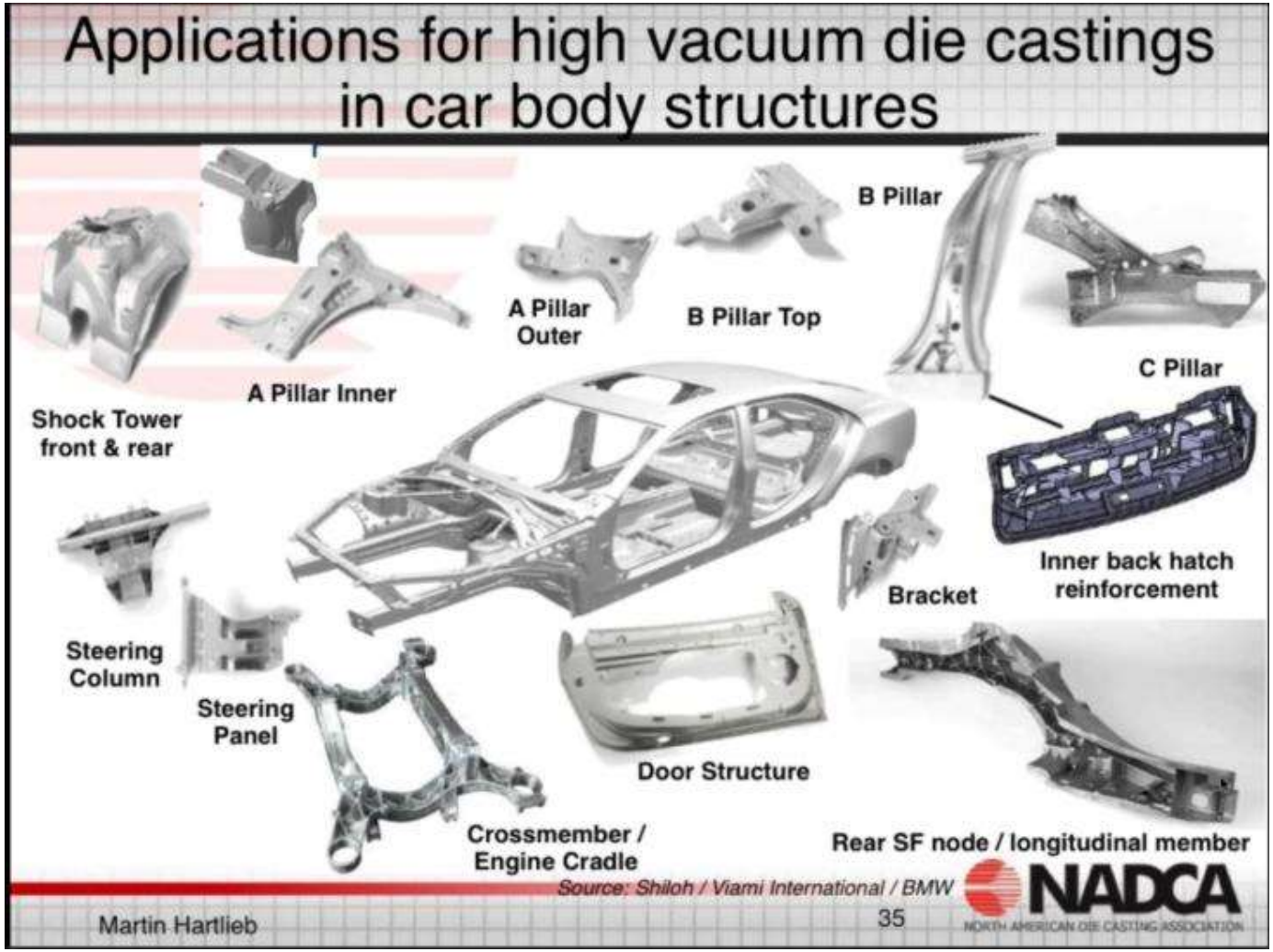
Structural Castings-

BIW Applications, the obvious applications



High Pressure Die Casting –
challenges and needs

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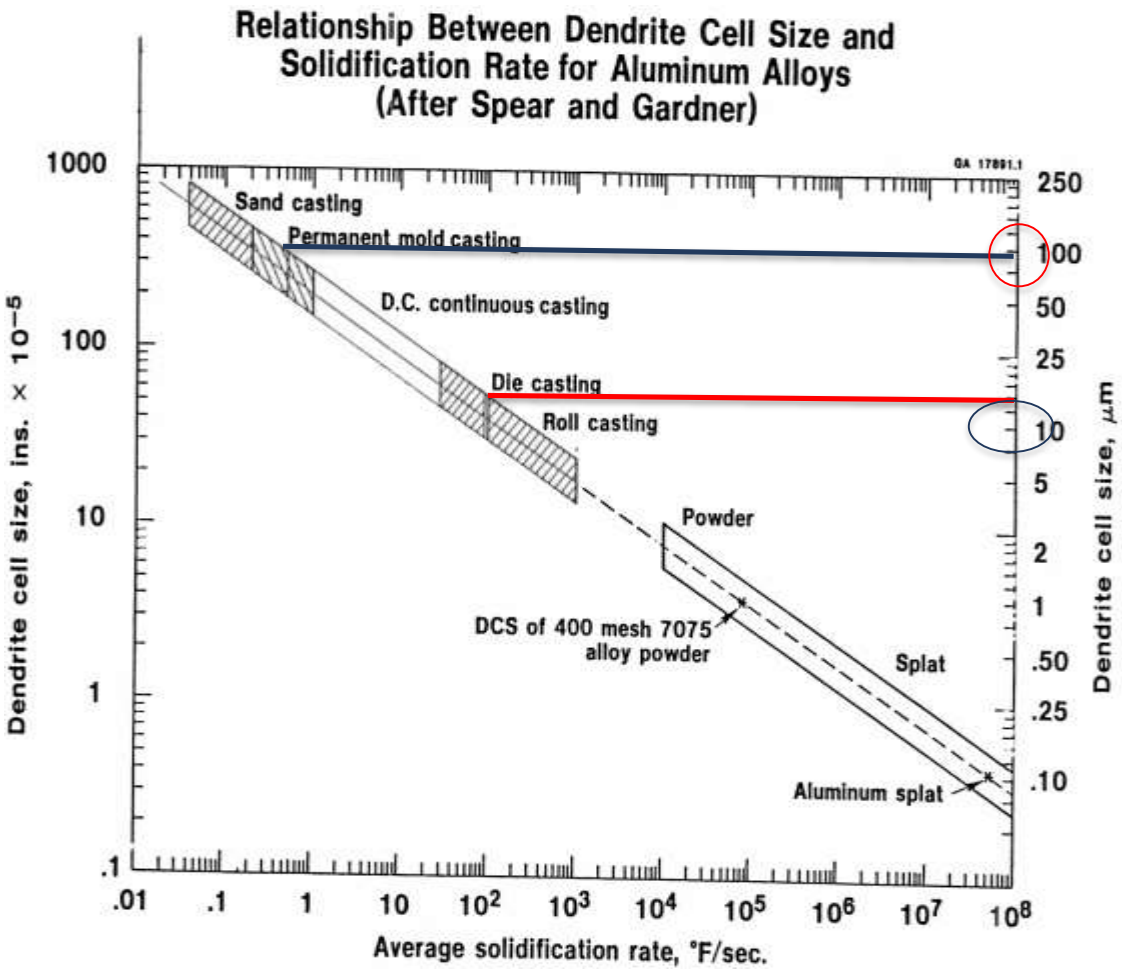
Where the structures are complex, many attachment points, with component/BOM unification => castings offer good solutions

Sand, Permanent mold, Squeeze, and High Pressure

- Characterize casting gravity feed and high pressure feed
  - Fill speed, calm progressive fill wave versus violent explosive splash
  - Vector bounce and entrapment
  - High pressure castings optimize lightweighting (mass, near net shape, reduced costs)

- Intricate and fine casting detailing (thin structures possible 1.5-2 mm)
- Fast solidification, small dendritic spacing - 7-12 micron SDAS
- Good properties in F state
- Can be enhanced primary alloys and with heat treatment (T4,T5,T6,T7)

Dendrite Size and Cast Processing



Dendrite spacing and properties are correlated

Closer the spacing the better the properties.

The faster the solidification, the smaller the SDAS spacing.

Structural HVHPDC >10 micron range with clean, dense material

At Shiloh, our ThinTech processing yields 6-9 micron spacing

The Simulation Challenge - HPDC

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Consider the modeling case (gravity fill vs high pressure fill)

- Metal velocity, molten at 15-20% fraction solid, pressured through 3 mm gates at approximately 1500-2500 ips for a variety of alloys
- Complex structures with small radii, thick and thin sections spread over casting shape
- Thicker casting sections solidify with less homogenous structures
- Time window for fill, 20-60 millisec,
- Volumes typically 10 - 30 lbs of materials flowing between the initial 15% solid fraction to potentially a 30% solid fraction
- Steel cooling in complex assembled die structures must be modeled to well predict solidification consistency

Structural Parts -
The challenge in the application

- All components that were overdesigned because the process generated poor capability relating to mechanical properties

- Typical fatigue strength at the thicker core of a casting (approximately 6-8 mm) is 50% of the fatigue strength of the skin

- Transforming the core area to tight dendritic structure, without contaminating elements and flows ------- that is the challenge

- The new materials, thin sections, and process technologies move us very close to the goal of homogeneous structures

- Then we lightweight, reduce the mass of even the typical loaded castings

Homogenous Structures

Inhomogeneous Material Properties

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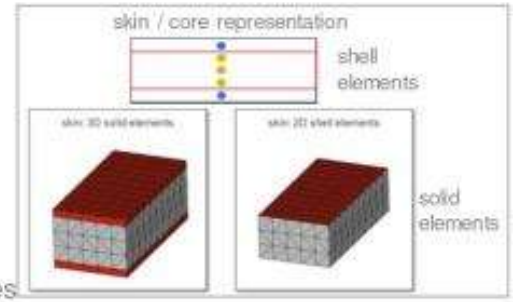
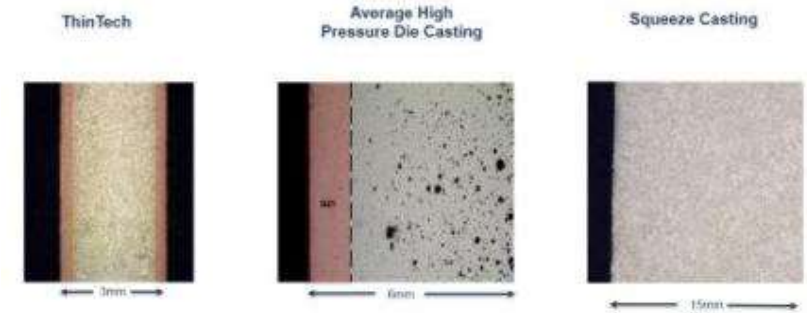
- **Skin-Core effect** for Mg alloys
  - Layer-wise composition
  - Different properties of both regions
- Skin
  - Fine microstructure
  - Ductile & high strength
- Core
  - Coarse microstructure
  - High porosity content
  - Brittle, low strength

→ High impact on mechanical properties

cross-sectional view





The "skin" typically reveals little or no porosity and has a dense microstructure. ThinTech results in 2 sided Skin with no porosity

The "skin" typically reveals little or no porosity and has a dense microstructure. Degradation in microstructure (presence of porosity) is observed beneath the "skin"

No "skin effect", uniform microstructure, and reduced gas and shrink porosity results in higher part **integrity**

Horst Lanzerath

Go Further

- Default assumption in CAE: homogeneous material properties
- Reality: properties are inhomogeneous

Challenges in Crash Modeling

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Challenges in Modeling Castings: Geometry

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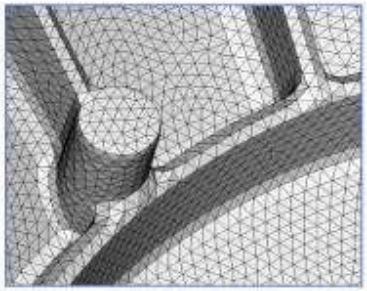
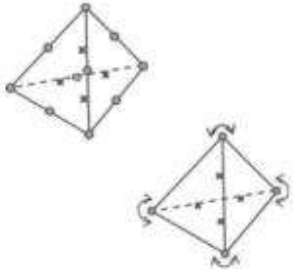
- Solid models recommended for
  - Complex 3D geometries
  - Massive parts
  - Transition areas
  - Intersections
- Use of 2nd order tetrahedrons
- Advantages
  - Automatic & fast meshing
  - Minor manual adjustments
  - Maximum geometry representation
- Challenges
  - Relatively small element sizes, small time-step
  - Longer computation times





Horst Lanzerath

Ford
Go Further

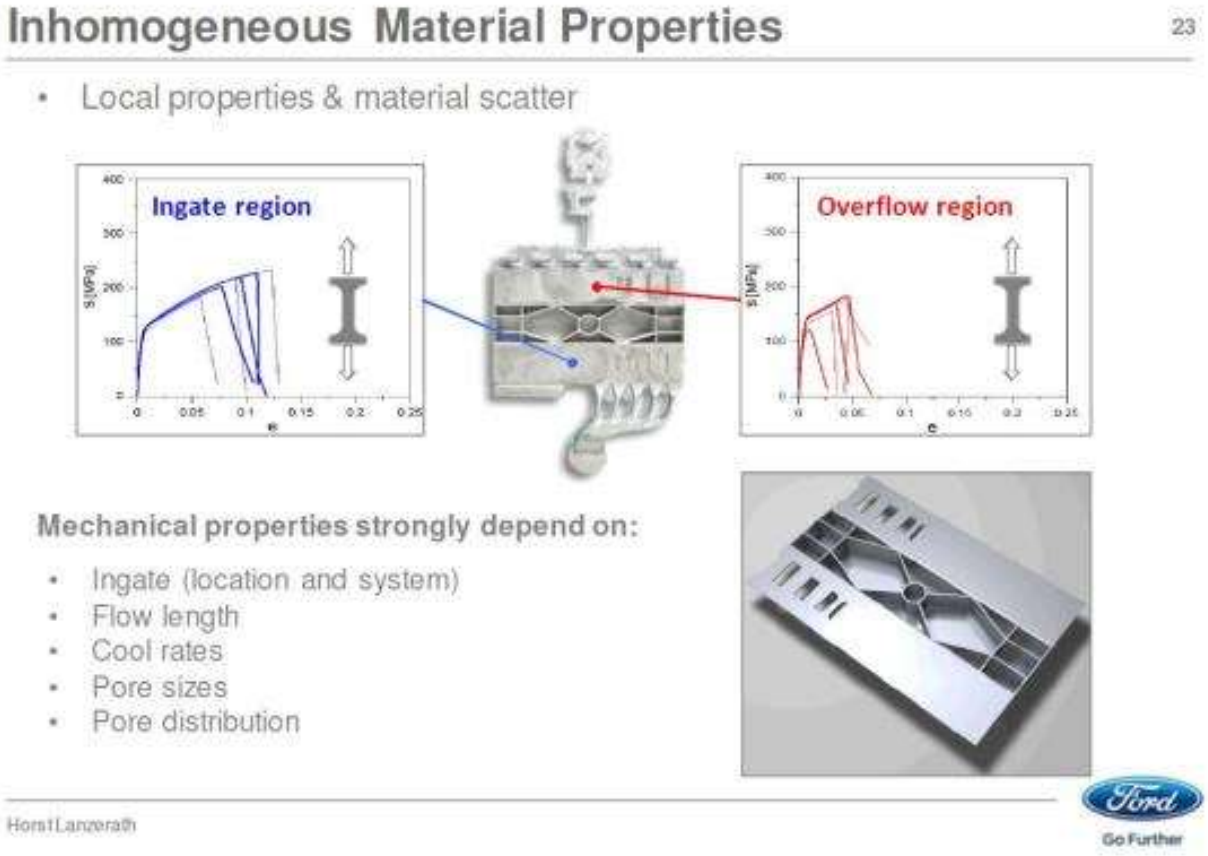
New prediction needs for the light weight materials

Shell modeling moving to solids with small radii

Computing power and speed

Move towards greater sophistication in prediction modeling

HPDC and Homogenous Structures



We must work towards more homogeneous structures

Free of oxide formations, impurities, flow segregation, with fast solidifying geometry

Shiloh Advanced Engineering

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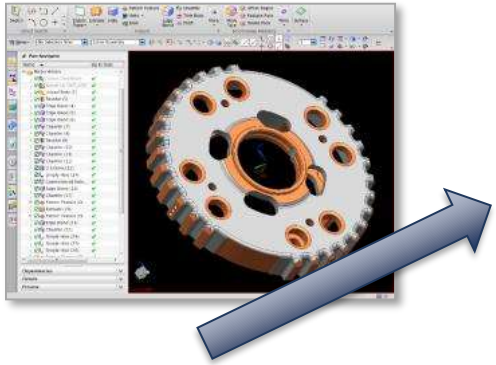
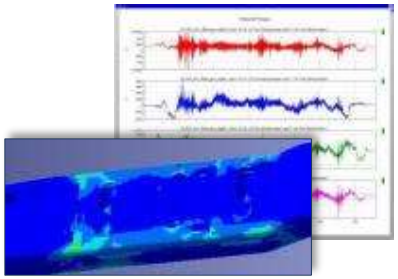


After the part modeling

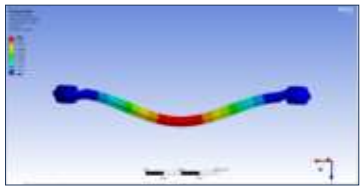
Areas of required analysis

A full range of CAE tools including Modeling, Mold Flow, and FEA analyses are applied based on product requirements

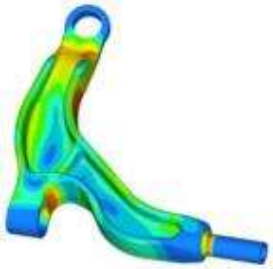
Component Stress Analysis



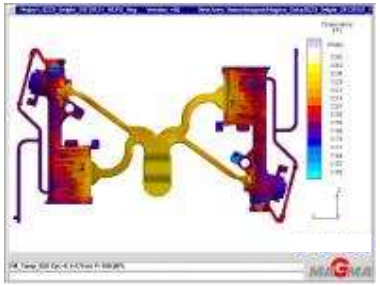
Fatigue Analysis



Buckling Analysis

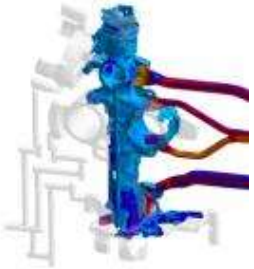


Design Optimization

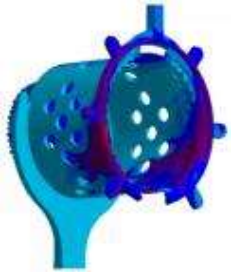


Fill Temperature

Solidification



Fill Velocity



Air Entrapment

Porosity Prediction

Simulation uses and tools

The tools we use for flow prediction and design

- Magma software (emulation of CFD)
  - Optimization
  - Flow simulation
  - Thermal simulation

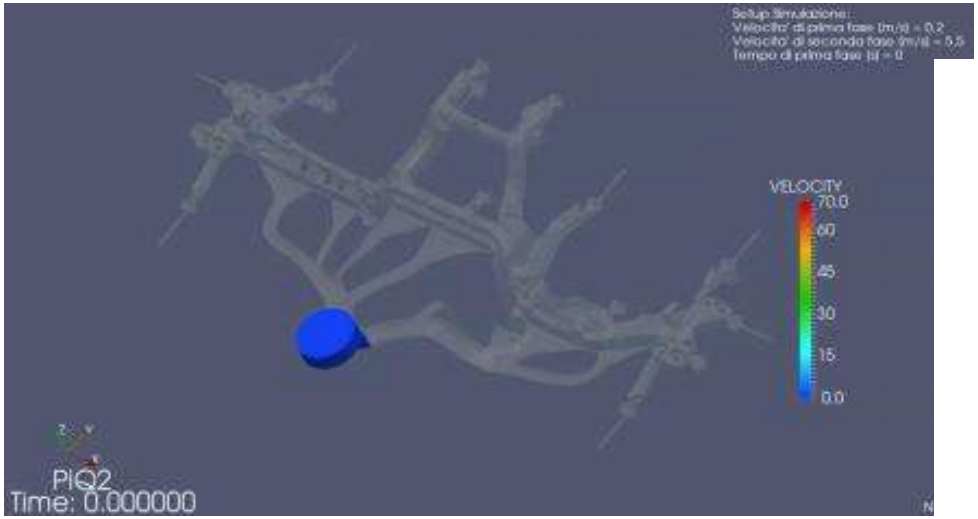
- Flow 3D (full CFD capability)
  - Flow simulation
  - Thermal simulation

- Logical tools applied to each geometric case

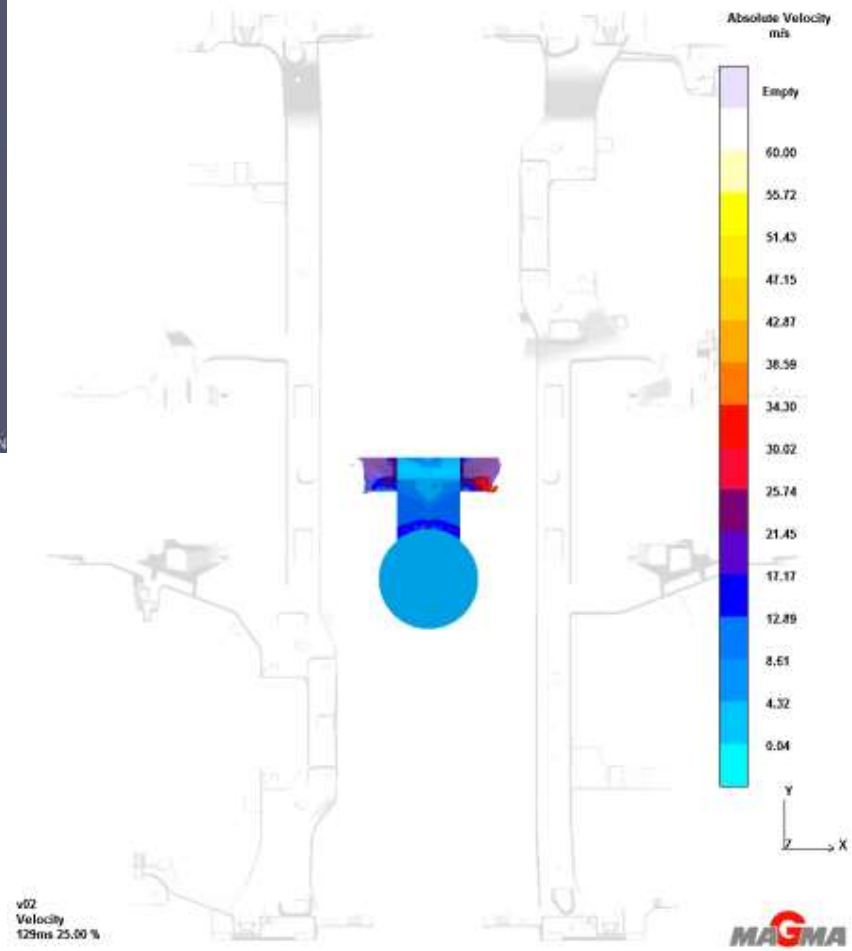
- Used on all castings, with multiple iterations required

Engineering Example

Metal flow simulation



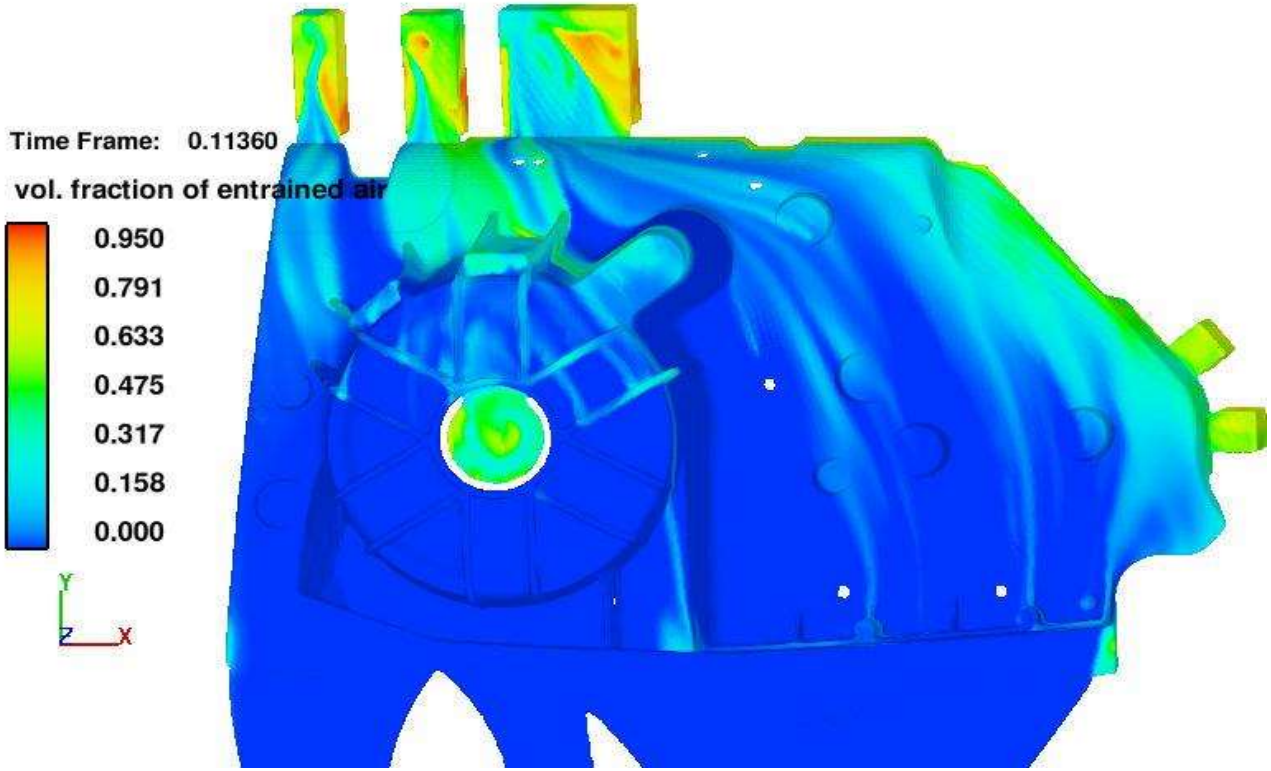
FLOW-3D



In house expertise with CFD
Gate design optimization via Flow 3D and Magma

Casting Design Support –
Process Simulation Analysis

Smooth, well integrated, metal flow, is required for high quality structural applications

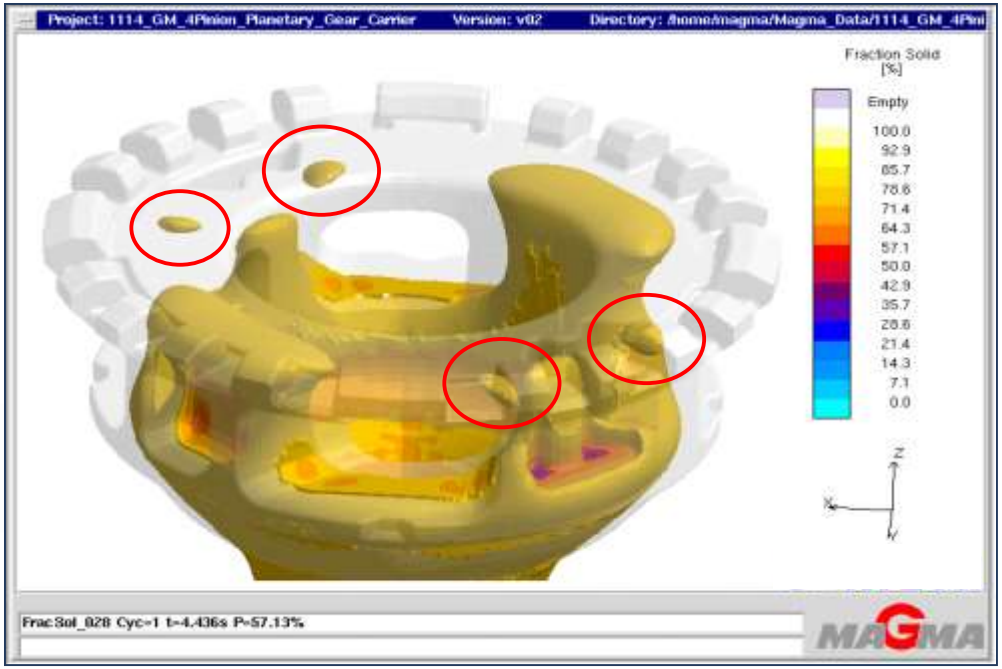


Solidification Predictions

On these loaded tooth applications, weakened areas of the structure due to shrinkage behavior is not acceptable

Prediction through effective simulation allows early design to remove potential defects

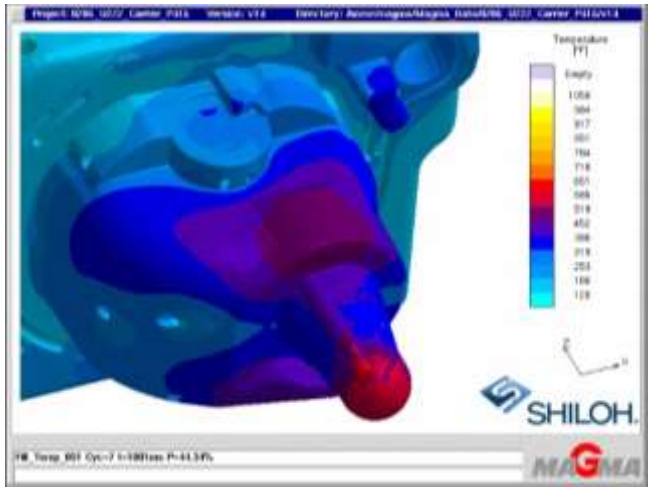
Cooling channel placement and adjustment removes potential cause of failure



Thermal Challenges –
Surface Temperature

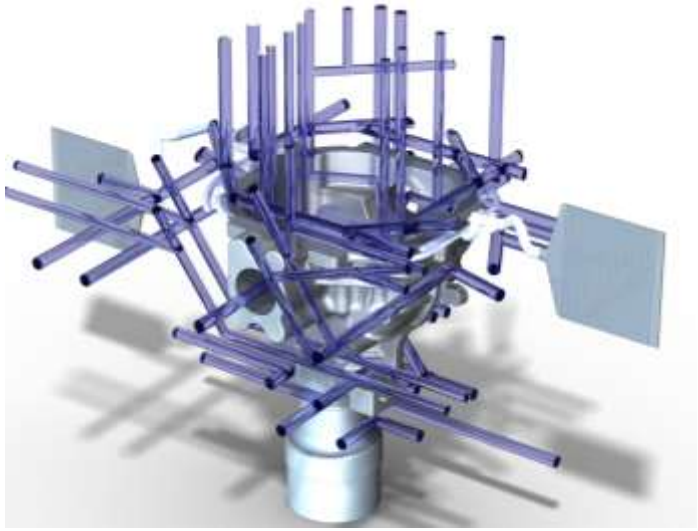
Cooling channel design throughout the die steel segments based on simulation is critical in launch success

Post launch modifications are prohibitively expensive



The complete cycle is simulated.

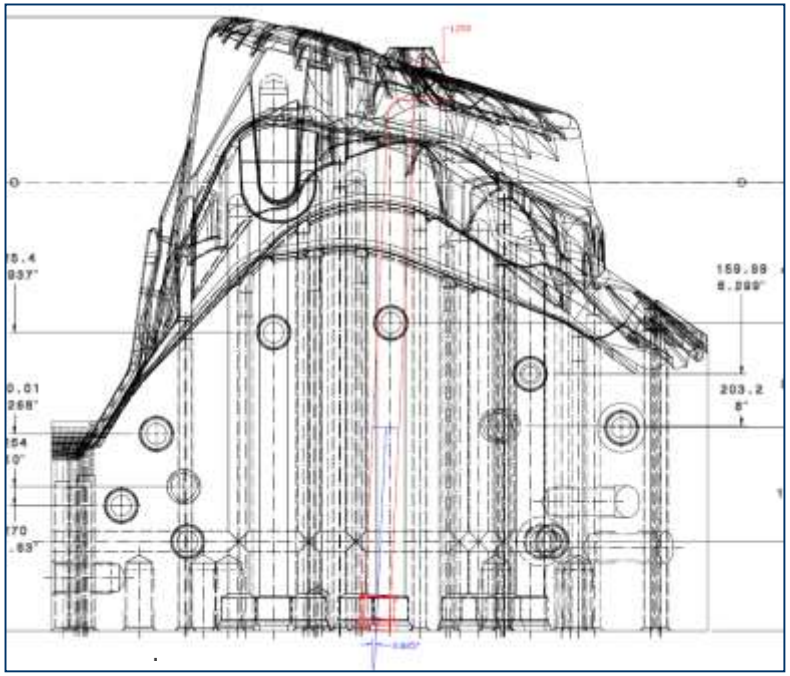
Cavity fill, die open, part extraction, die spray, die blow-off, and die process stabilization are all part of the simulation predicting the casting quality outcomes.

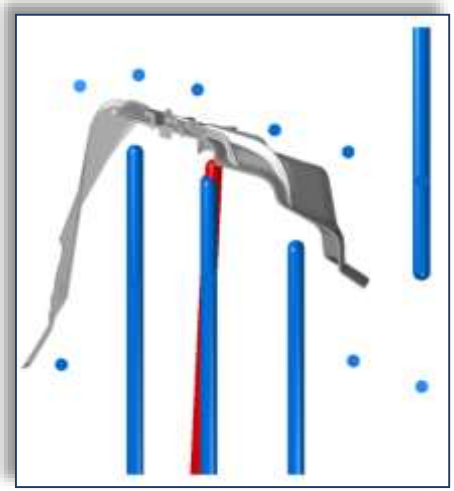


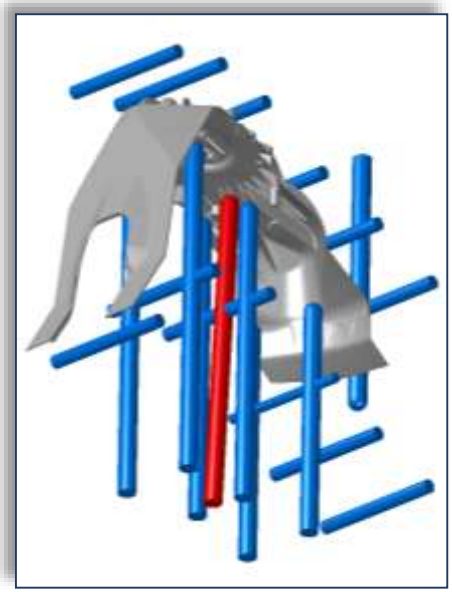
Cooling Channels –
a typical problem

Ongoing improvement of dome area thick section within thin feed zones

Baffle structure proposed within existing cooling matrix

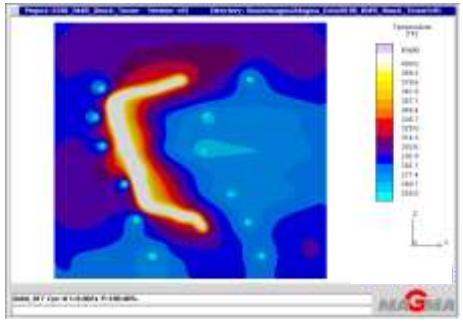


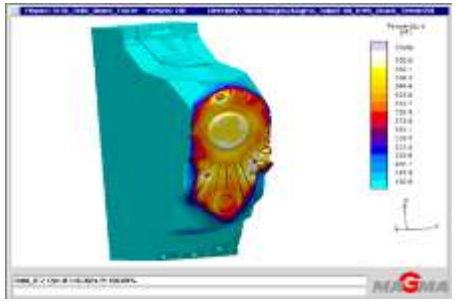


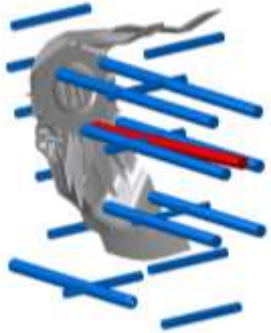


Cooling Channels –
a typical problem with test iterations

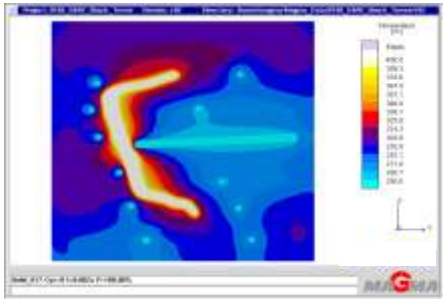
Iteration 1. Current production cooling, all circuits at 250º F (Oil)

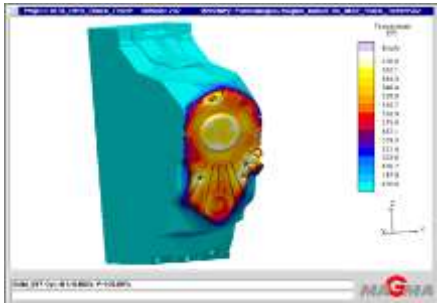


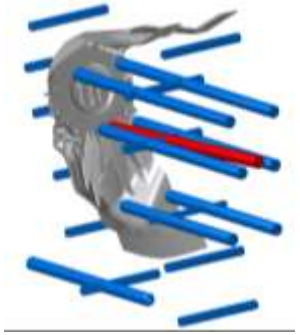




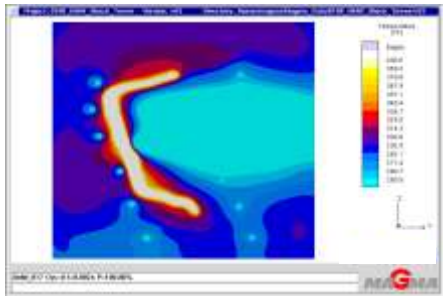
Iteration 2. Added baffle. All circuits at 250º F (Oil)

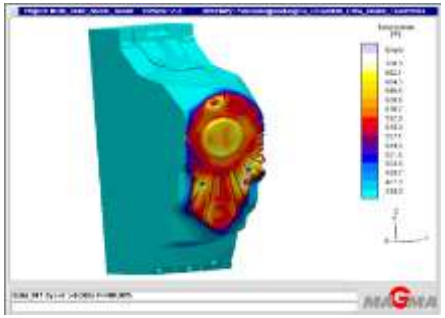






Iteration 3. Added baffle, dome circuits changed to 150º F (Water)





The Challenge and ORNL Collaboration

- Cooling Prediction is critical in solidification control
- Owing to the multi-physics involved in metal casting and the boiling of flowing liquids in micro-channel cooling, High Performance Computing is required during process development to obtain accurate data on simulation
- Previous simulation trials were conducted for a high heat flux removal application using a model with 4.3×10^4 cells
- Shiloh selected this number of cells based on its limited computing power (64 CPUs and 250GB of memory)
- More powerful computing power is required to completely and correctly model 3D-shaped cooling channels

Project Outline

Task1:

- Micro-channel cooling HPC models
- Testing of boiling models

Task 2:

- Heat transfer correlations for micro-channel cooling specific for HPDC

Task 3:

- Assessment of model accuracy for micro-cooling HPDC
- Validation the model for heat transfer coefficient. Identify an optimum channel configuration.

ORNL Presentation

Typical Applications

Shiloh Application areas

Conclusions

Benefits

- Successful completion of the project can provide the right tools and guidelines to correctly model and implement micro-channel cooling systems in HPDC

- Benefits include:
  - Increased die life
  - Improved mechanical properties of finished parts with fewer secondary post-casting operations
  - Cycle time reduction
  - Weight reduction and downstream energy savings
  - Validation of our modeling solutions
  - Metal flow behaviors predicted, better homogeneity
  - Improved design activity targeted first off success

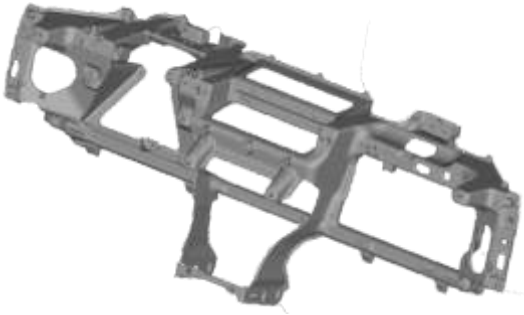
Interior Structures

Cross car beams

- Multi-material
- Multi-application
- Multiple value propositions

Hybrid Solutions:
Customizable for any requirement

Magnesium Solutions:
Ultra lightweight and high performance



Steel Solutions:
Strong and affordable

Able to provide a range of alternative solutions for OEM design needs

Chassis, Frames & Suspensions

Frame Rails and Support

- Multi-material
- Multi-application
- Multiple value propositions

Frame Rails:
Multi-material and multi-thickness

Shock Tower:
Optimized multi-material solution

Engine Cradle:
Multi-material, high-strength cross members

Rear Rails:
Lightweight, stiff and strong

Portfolio of products covering frame sub-systems

Case Study

Design optimization of aluminum frame structure

SHILOH
Lightweighting without compromise.™

Original Design

- Traditional low pressure heavy aluminum casting design
- Expensive machining and joining to produce the frame segment
- Multiple components combined to create the structure

Shiloh ThinTech® High Integrity Lighter, Stronger, Better Value

- Shiloh ThinTech® process
  - Structural integrity
  - Designed for welding and riveting
  - Elongation greater than 12%
- 10 lb. weight savings per vehicle
- 50% reduction in machining requirements
- One-piece cast design eliminated sub-assemblies

We make aluminum LIGHTER

Case Study

Design optimization of pickup truck rear

Original Design
Heavy Loaded Beam Axle

- Traditional low pressure iron casting design
- Weight: 68 lbs.
- Significant secondary machining operations
- Limited opportunity to improve value proposition

Shiloh High Integrity
Squeeze Cast Design

- Disruptive groundbreaking technology; first to produce in aluminum
- Shiloh proprietary squeeze cast process
- 44 lb. weight reduction per vehicle
- 65% weight reduction over iron
- Near net shape reduces machining
- Lightest beam axle housing in the marketplace – no compromise in any product attributes

Conclusions

- Engineer and optimize the best material(s) and processing innovation to support the customer transportation systems
- Optimize the mass and properties of our structures, with multi-material solutions
- Improve our simulation/analysis results correlated to our innovative processing
- Use our CAE results to achieve the most consistent castings with narrow capability
- Improve the speed of analysis (optimization, prior to simulation)
- Partner with Industry experts to successfully remain ahead of the prevailing technologies, supporting our Global customers with innovative solutions

Shiloh Industries

light, safe, quiet, strong

no compromises

Thank you for your attention

Any questions?

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