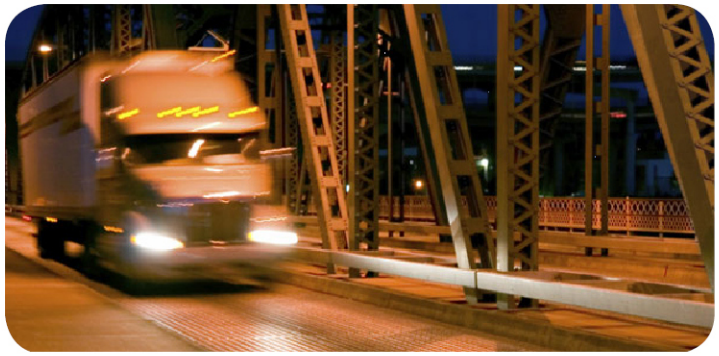

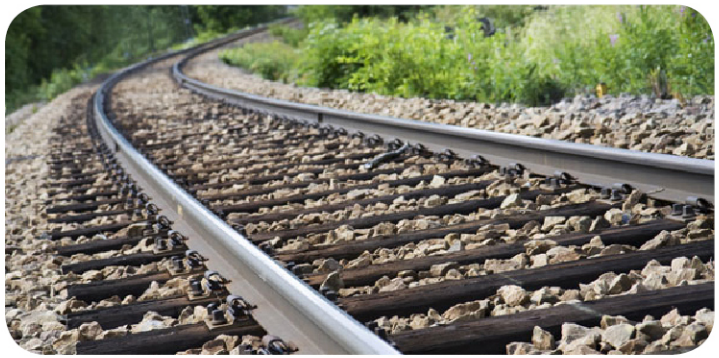

GREDE

Casting Integrity®

Advantages of Pouring Compacted Graphite Iron Castings Using the Lost Foam Casting Process

Virginia Tech

Invent the Future

Acknowledgments

- *Previously presented at the AFS 115th Metalcasting Congress*
- *Published in 2011 AFS Transactions*

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VirginiaTech
Invent the Future

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SinterCast
— Supermetal CGI —

Harry Littleton, Jud Dunlap, Robin Foley

UAB

Jamey Reynolds, Bill Harvey, Jim LeCroy

Grede Columbiana

Compacted Graphite Iron

Improve performance, increase fuel economy, increase engine durability while reducing weight, noise and emissions

Property Comparison

Compared to Gray Cast Iron

- 70-75% higher tensile strength
- 40-45% higher stiffness
- Double the fatigue strength

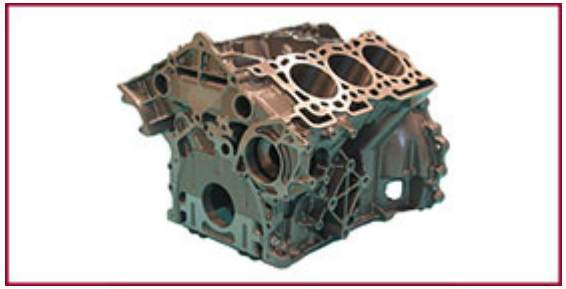
Compared to Cast Aluminum

- 70-75% higher tensile strength
- Two times the stiffness
- Five times the fatigue strength

Background

SinterCast-CGI engines are available in 30 different passenger vehicles and 12 car brands

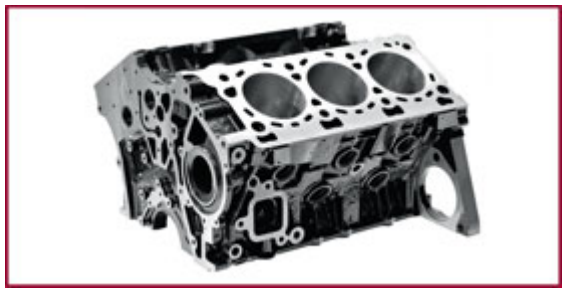
Audi 3.0 liter V6
Audi, Porsche and Volkswagen



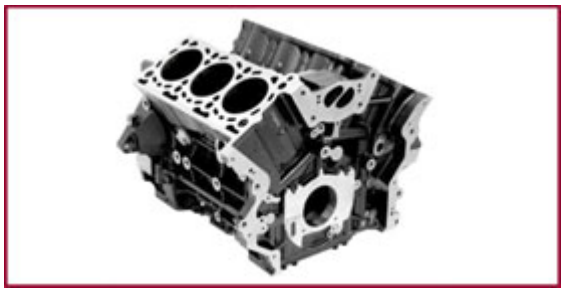
Ford 2.7 and 3.0 liter V6
Citroen, Ford, Jaguar, Land Rover, Peugeot and Range Rover

Ford 3.6 and 4.4 liter V8
Range Rover

Ford 6.7 liter V8
Ford Super Duty Pick-up Trucks



Hyundai 3.0 liter V6
Hyundai and Kia

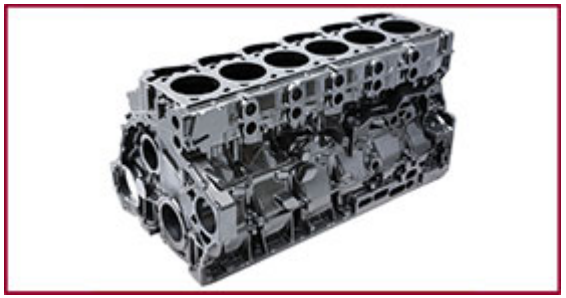


VM Motori 3.0 liter V6
Jeep Grand Cherokee

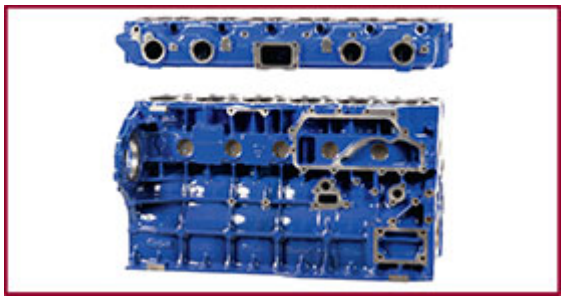
Pictures courtesy of SinterCast

Background

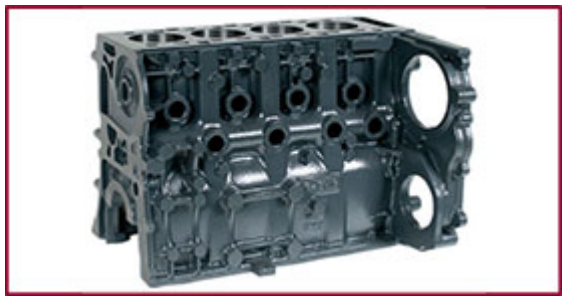
SinterCast-CGI technology is used in 14 different engines for the production of 17 different commercial cylinder blocks and heads



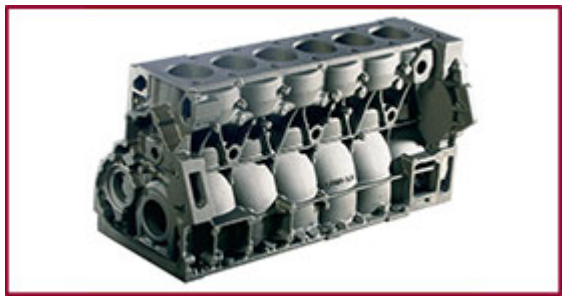
DAF 12.9 liter cylinder block & head
MX Engine Series



Ford-Otosan 7.3 and 9.0 liter
cylinder block & head
Ecotorq Engine Series



Hyundai 3.9 and 5.9 liter cylinder blocks
Hyundai 5.9, 9.9 and 12.3 liter cylinder heads



MAN 10.5 and 12.4 liter cylinder blocks
D20 and D26 engines

Navistar 6.4, 10.5 & 12.4 liter cylinder blocks
MaxxForce™ 7, 11 and 13 Engines

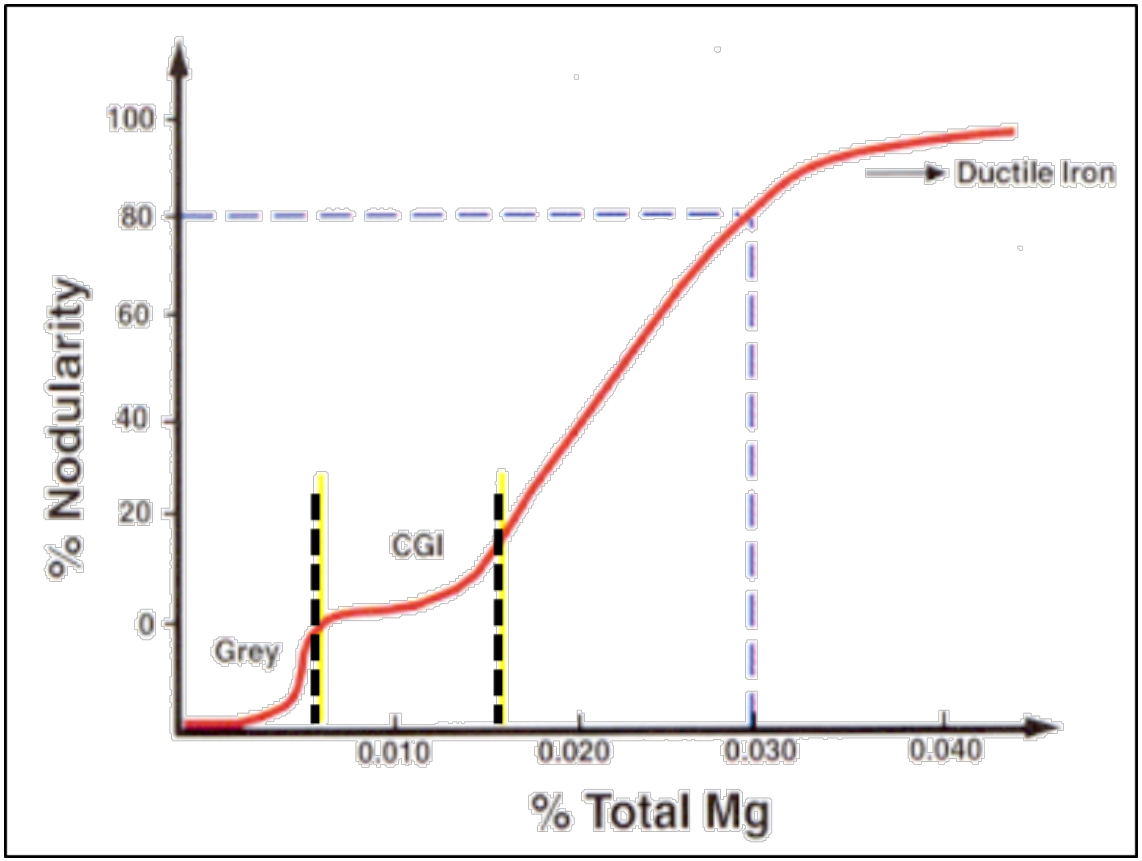
Scania 16.4 liter V8 cylinder block
R-series Truck Engines

Pictures courtesy of SinterCast

Background

- A gray iron skin, which reduces fatigue life, is present on all current production, CGI, cylinder block & head castings
- No production CGI cylinder blocks or heads are produced using the lost foam casting process
- A preliminary study at UAB in 2008-2009 indicated that little or no gray iron skin was produced using the lost foam casting process

Background



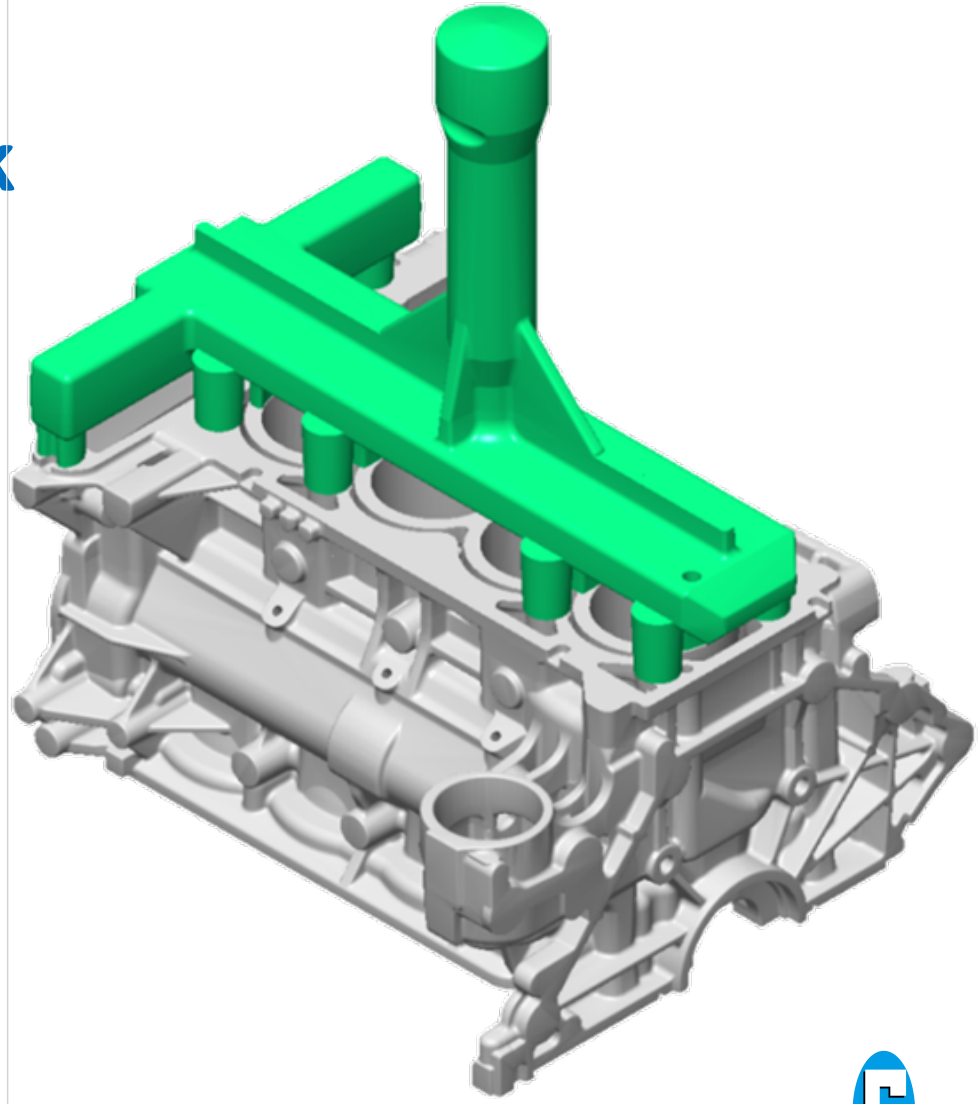
Ref: SinterCast Information Brochure

- **CG iron is difficult to produce due to a small processing window**

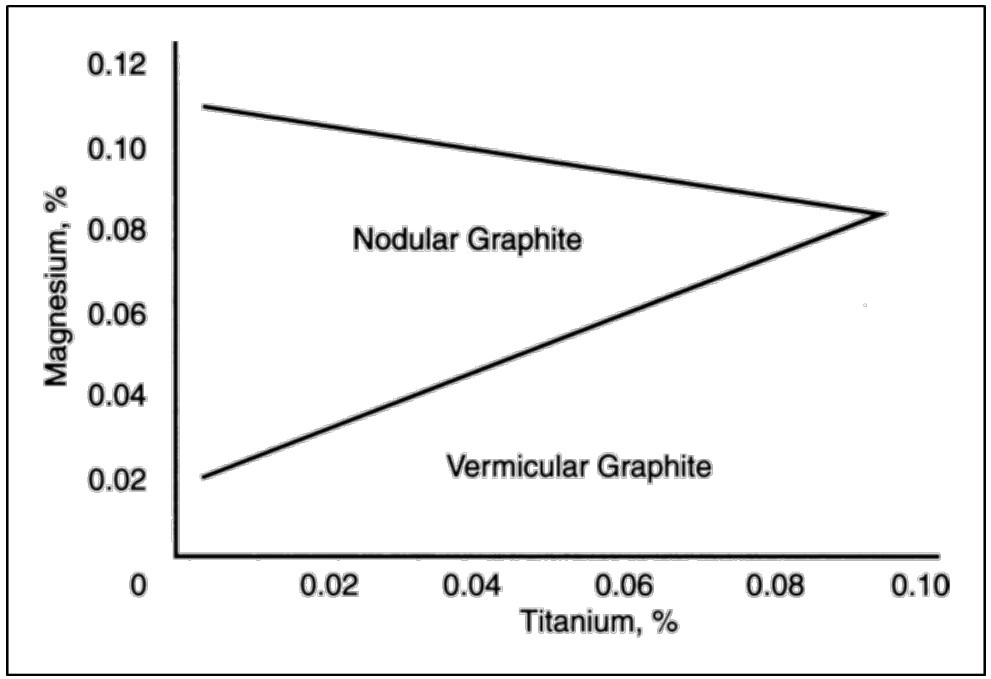
Preliminary Study – UAB Casting Lab

4-Cylinder Engine Block

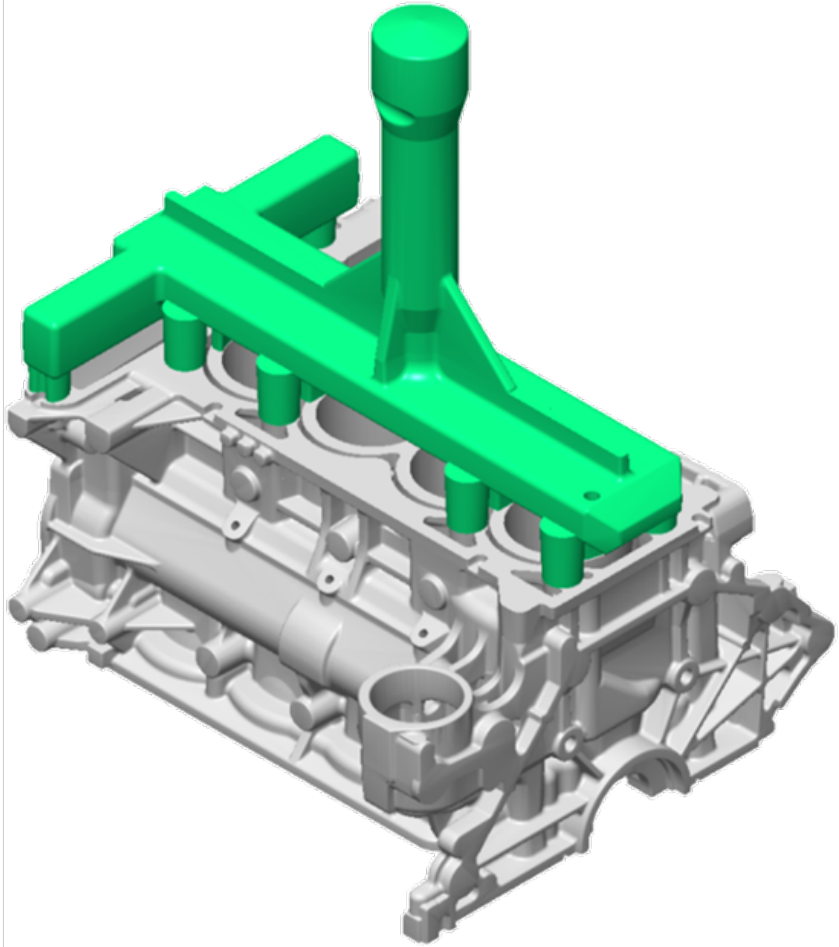
- designed for aluminum
- EPS foam
- silica-based coating
- top gated



Preliminary Study -- Lab



Ref: The Sorelmetal Book of Ductile Iron, Rio Tinto Iron & Titanium Inc.

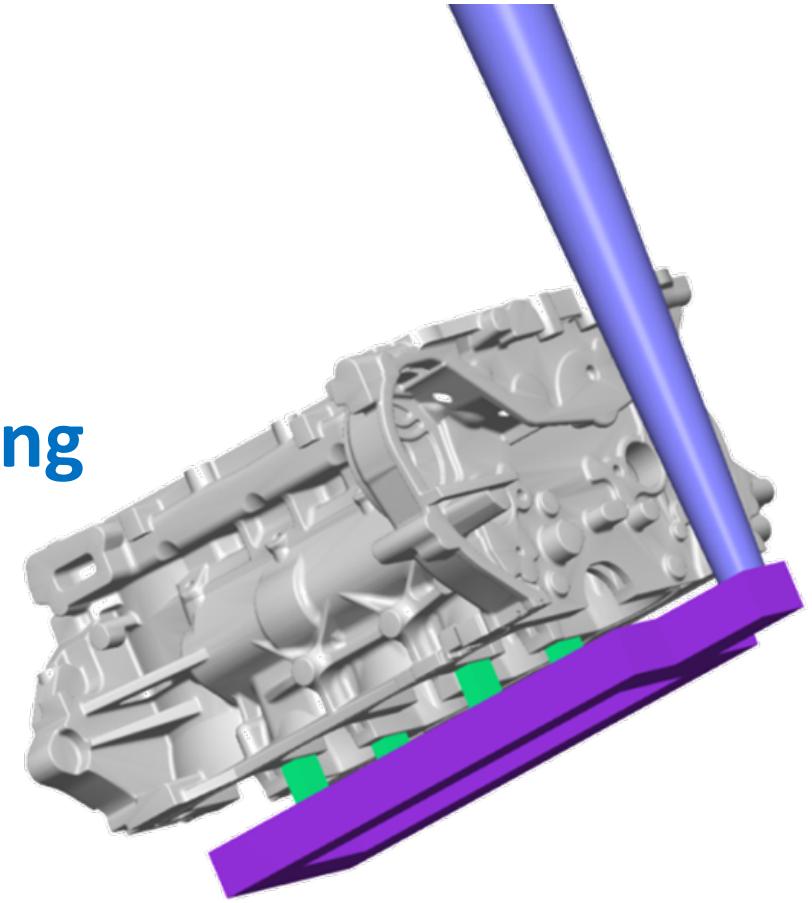


- Poured at UAB using Ti to control nodularity

Preliminary Study – Production Foundry

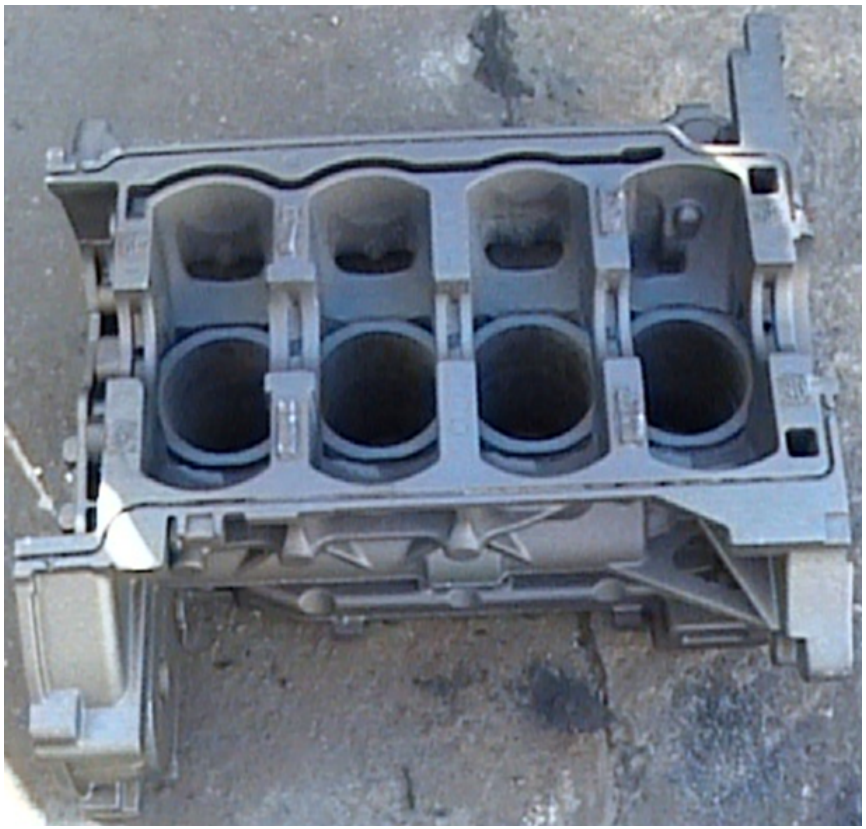
4-Cylinder Engine Block

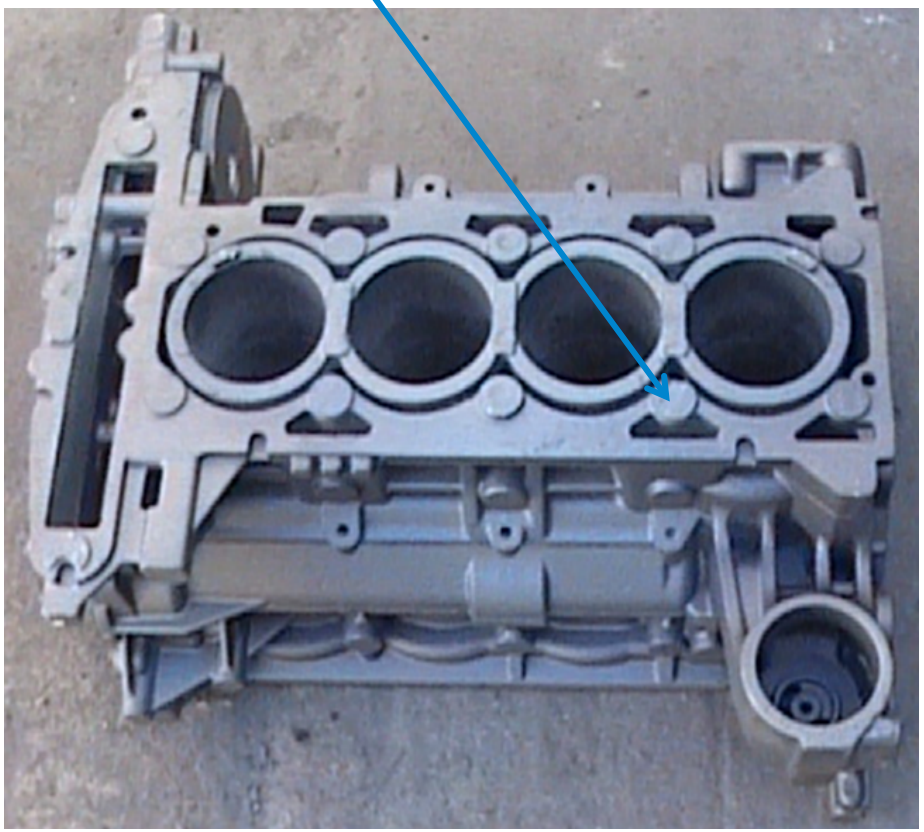
- designed for aluminum
- EPS foam
- changed to mica-based coating
- changed to bottom gating



- Poured at a production lost foam, iron foundry using low Mg and a little Ti (0.13 wt%) to control nodularity

Preliminary Study – Production Foundry

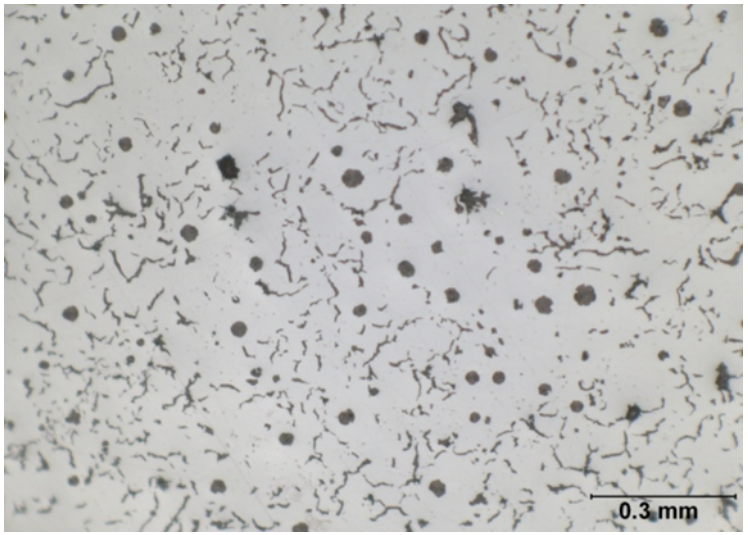




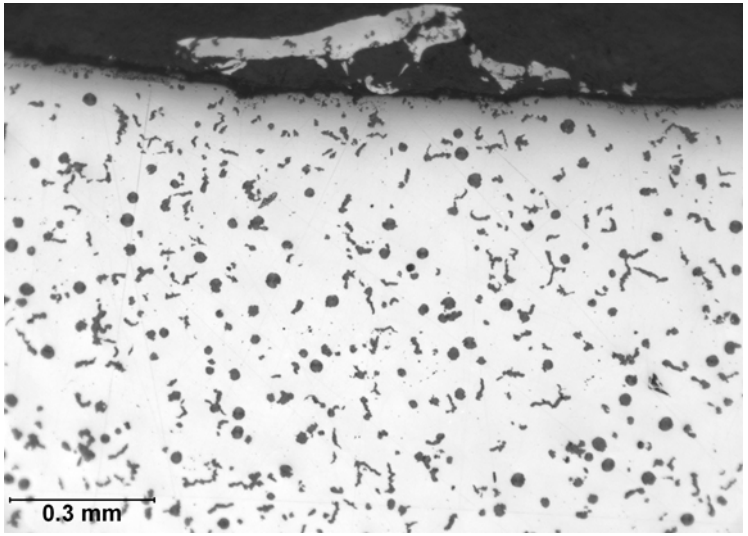
- Good castings with only one small spot of lustrous carbon on deck face

Preliminary Study – Production Foundry

Good CG microstructure



No flake graphite skin

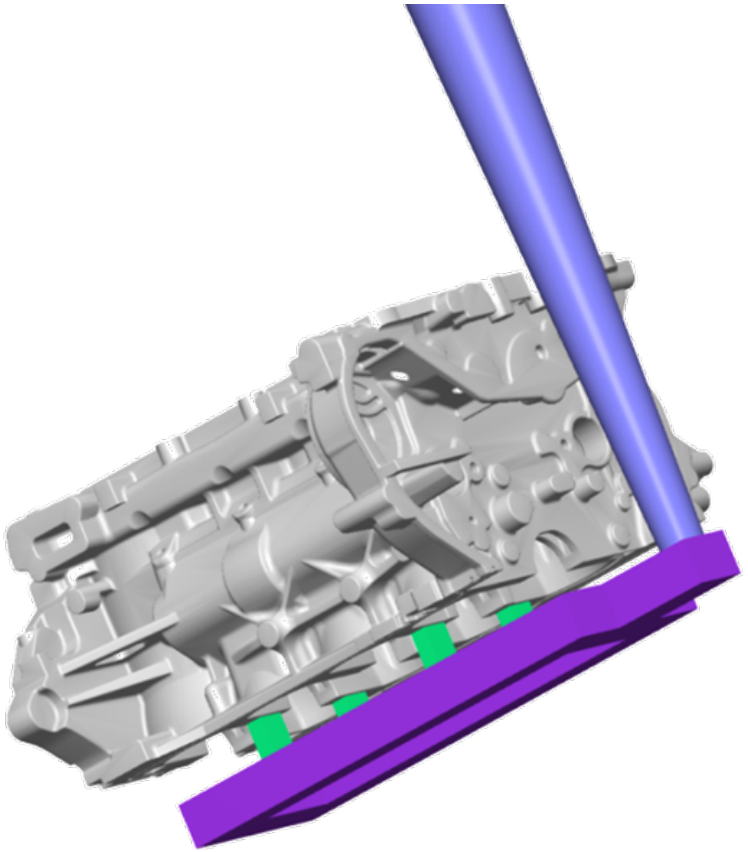


New Study

Production Foundry using the SinterCast Process

4-Cylinder Engine Block

- designed for aluminum
- EPS foam
- mica-based coating
- bottom gating



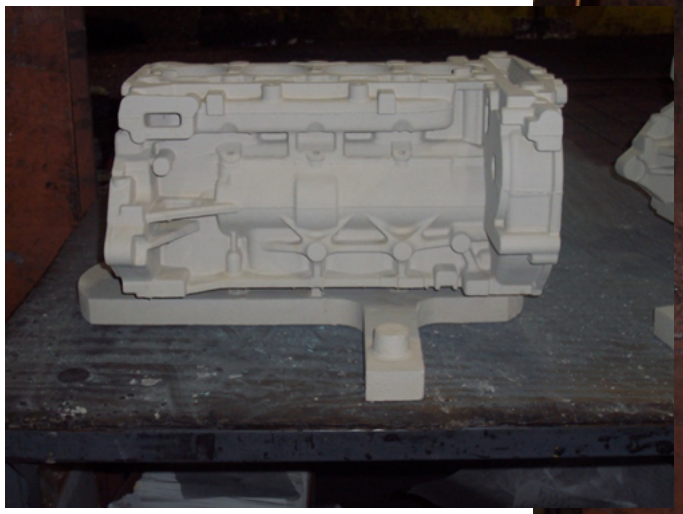
- SinterCast process to mirror high volume production
  - no titanium

New Study

Production Foundry using the SinterCast Process

- Four Casting Trials
  - time for SinterCast system to “learn” foundry process
  - general review of casting quality
- Microstructure
  - bulk and surface
  - nodularity and “skin” depth measurements
  - nodularity by area (ISO 16112:2006(E)):
    30 fields of view at 200x
- Tensile Properties

Casting Trials at Production Foundry



- mica-based coating
- bottom-gating
- sandwich treatment
- SinterCast mini-system 3000

Casting Trials using SinterCast Process

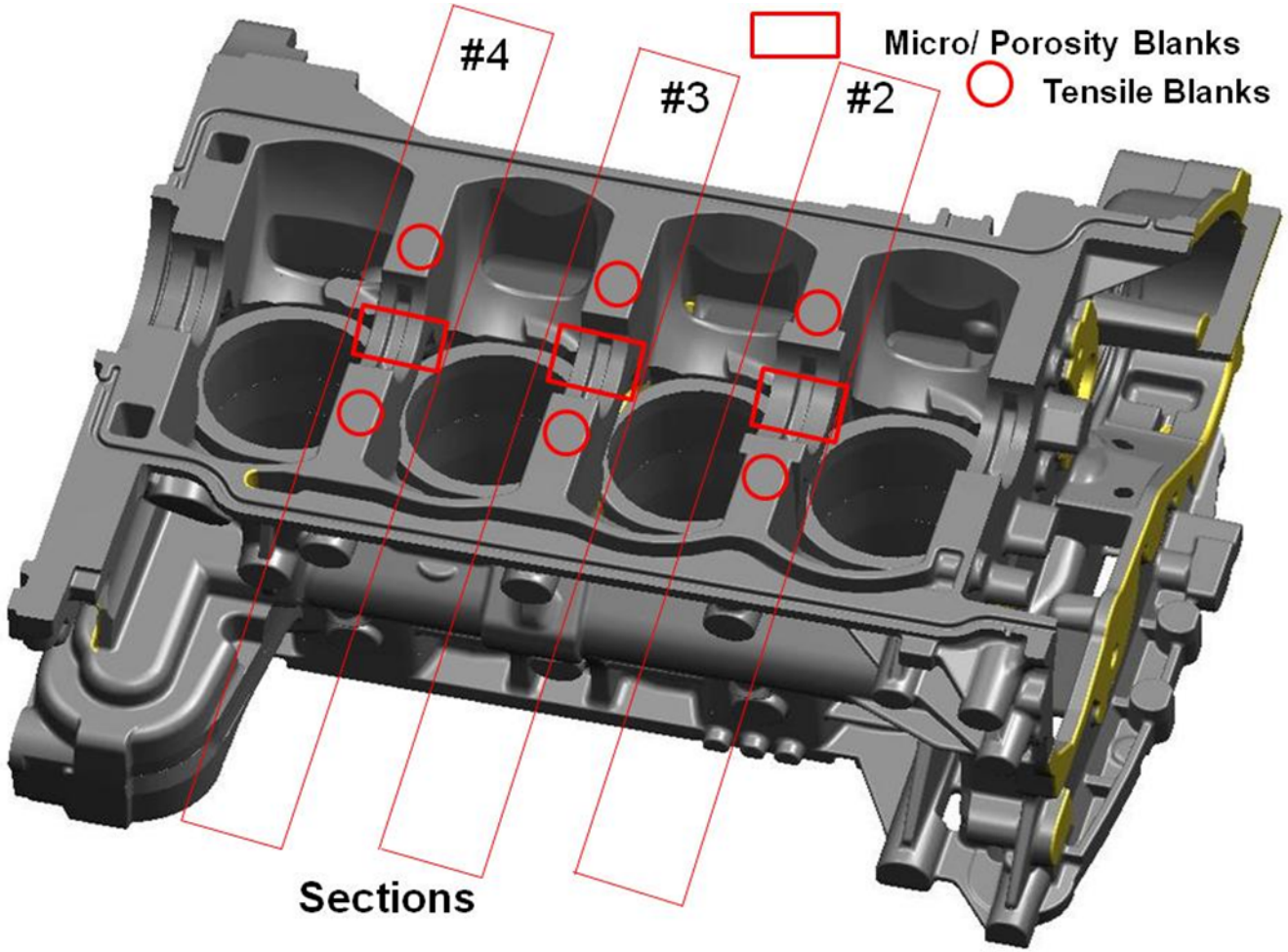
- **Four Trials**
  - 1336°C, 1378°C, 1413°C, 1454°C pouring temperatures (scrapped first casting – poured too cold)
  - 3.42-3.63 C, 2.10-2.16 Si, 0.27 Mn, 0.31 Cu, 0.002 Mg, 0.010 Ce, 0.007-0.009 S (final chemistries)

Casting Trials using SinterCast Process

- Visual examination revealed no obvious fill defects and no lustrous carbon defects were noted on the castings.

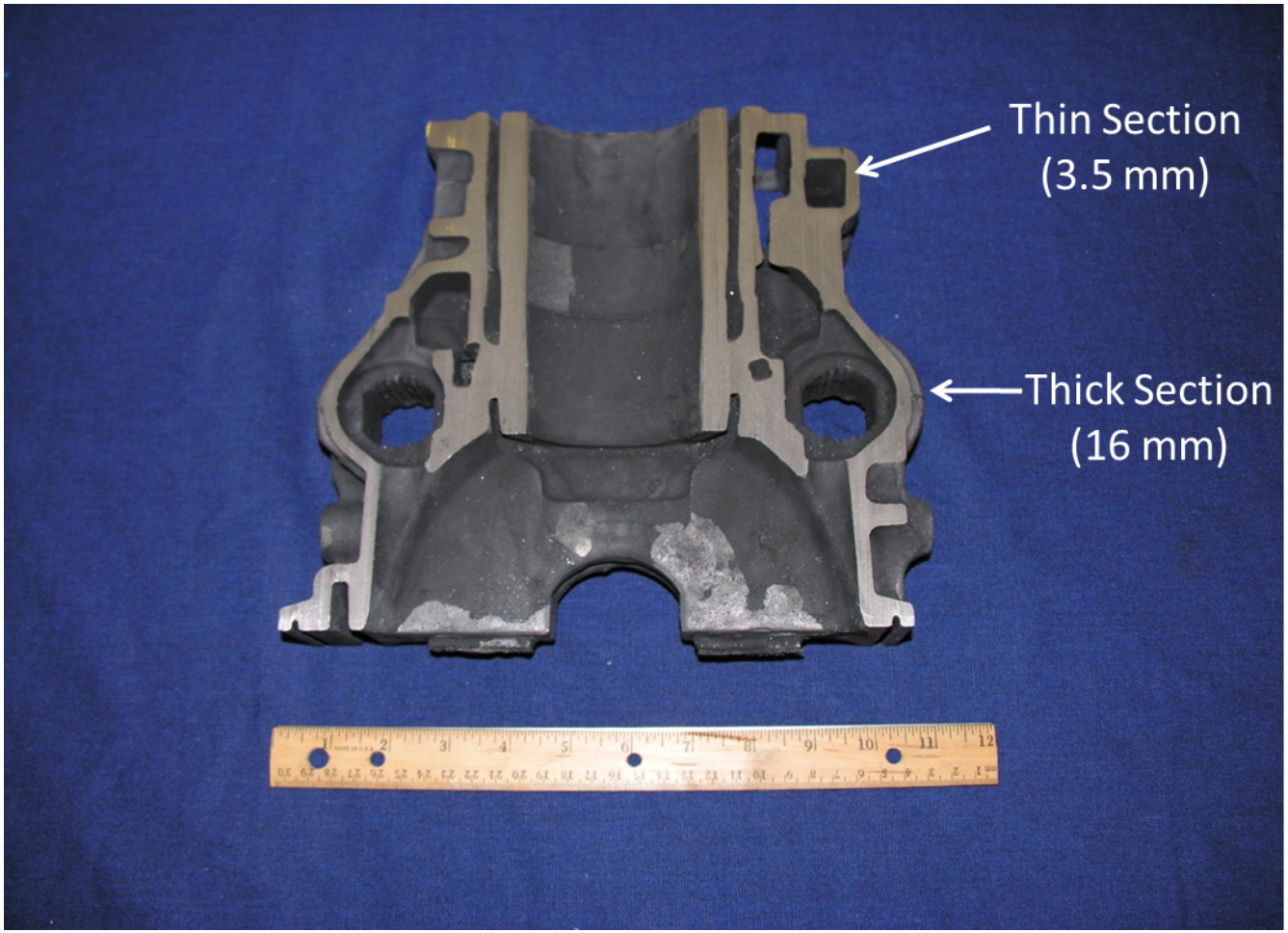
- However, a more thorough examination would have been needed to determine if the castings were suitable for engine build.

Sampling



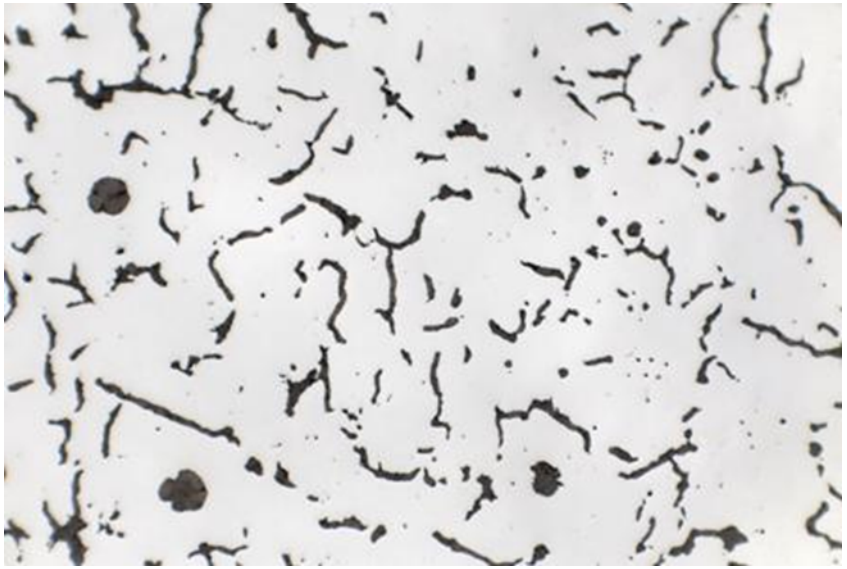
- **Cross sections through bearing blocks**

Sampling



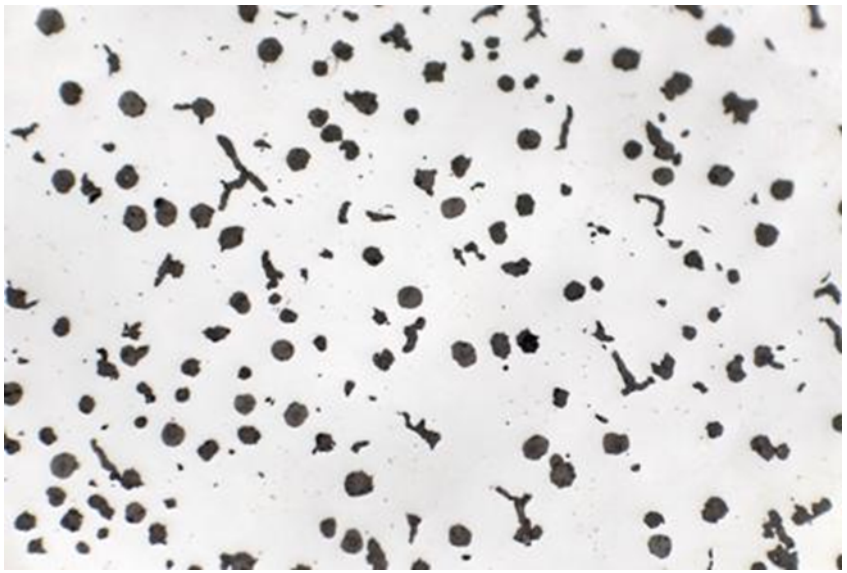
- Cross sections through bearing blocks
- Thick & thin section sizes examined metallographically

Bulk Microstructures



Thick Sections

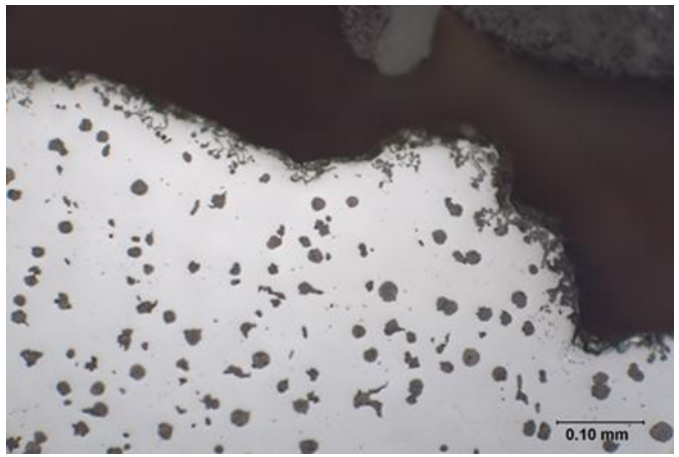
- 10 to 15% nodularity

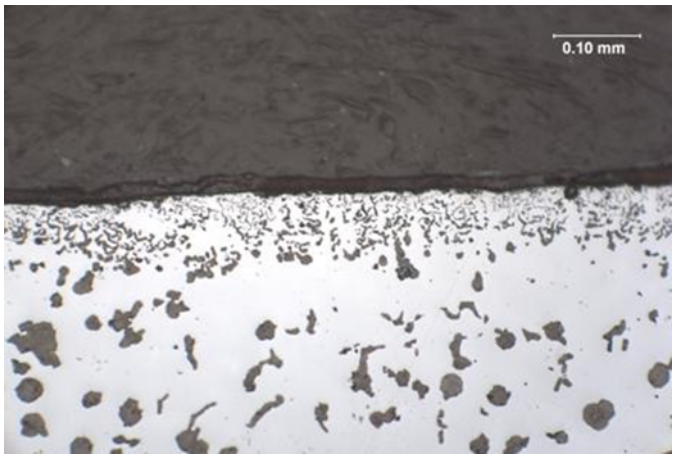


Thin Sections

- 48 to 64% nodularity
- nodularity decreased with increasing pouring temperature

Surface Microstructures - Skin

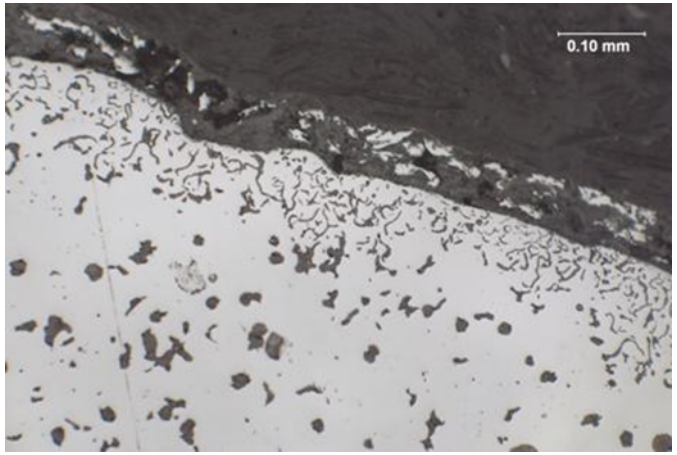


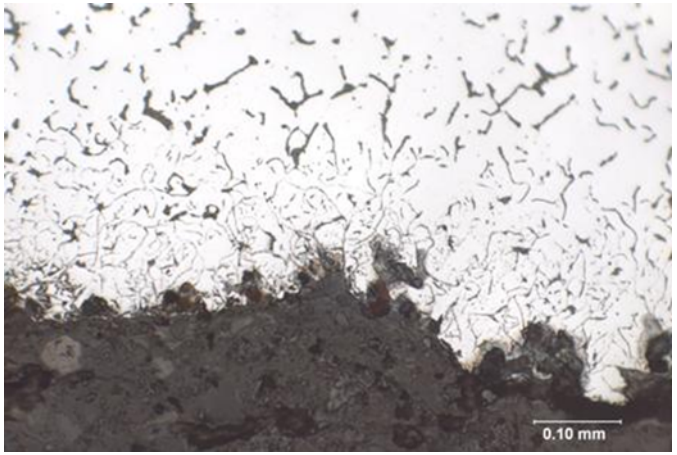


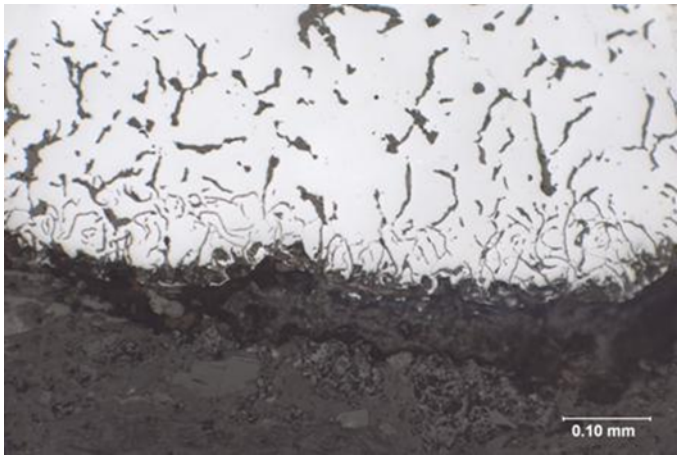
Thin Sections

- 0.014 to 0.100 mm thick
- not flake, but did have higher graphite volume fraction

Surface Microstructures - Skin



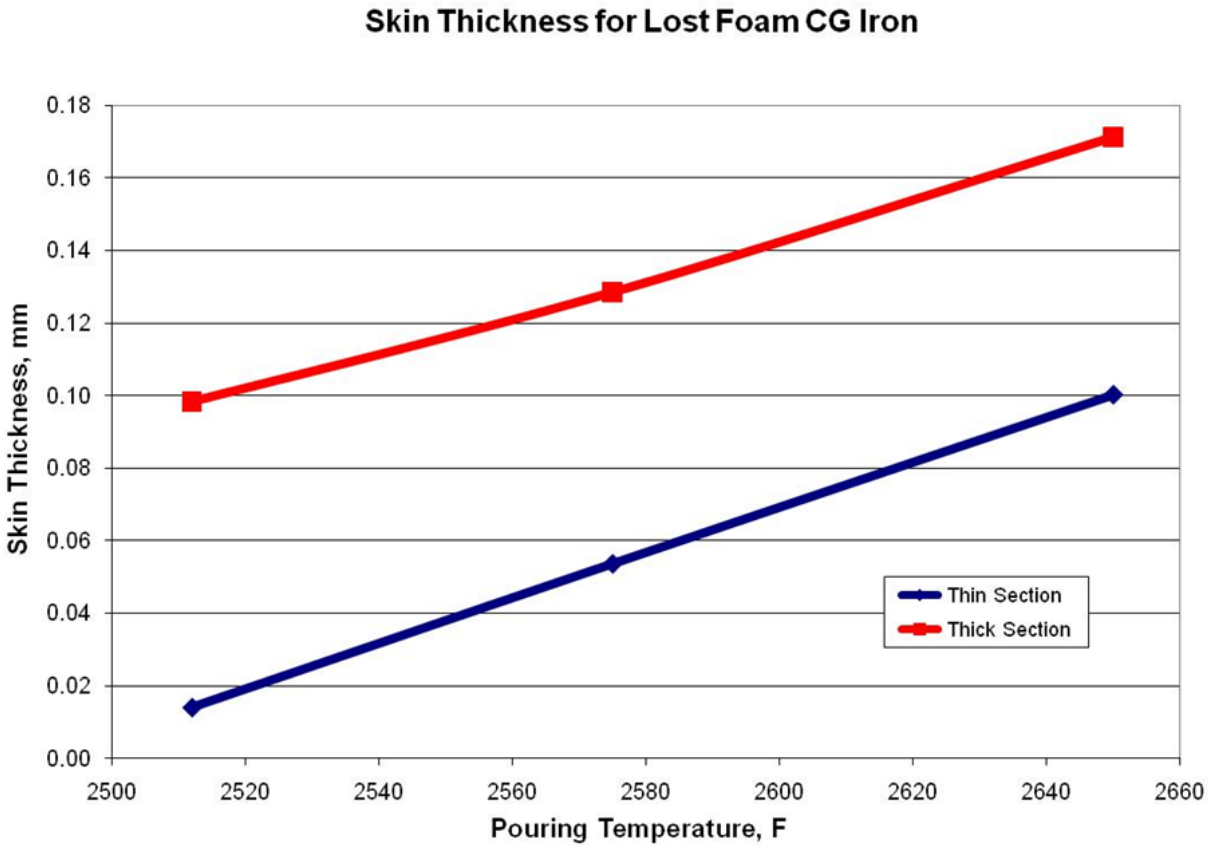




Thick Sections

- 0.098 to 0.170 mm thick
- not flake, but did have higher graphite volume fraction

Surface Skin

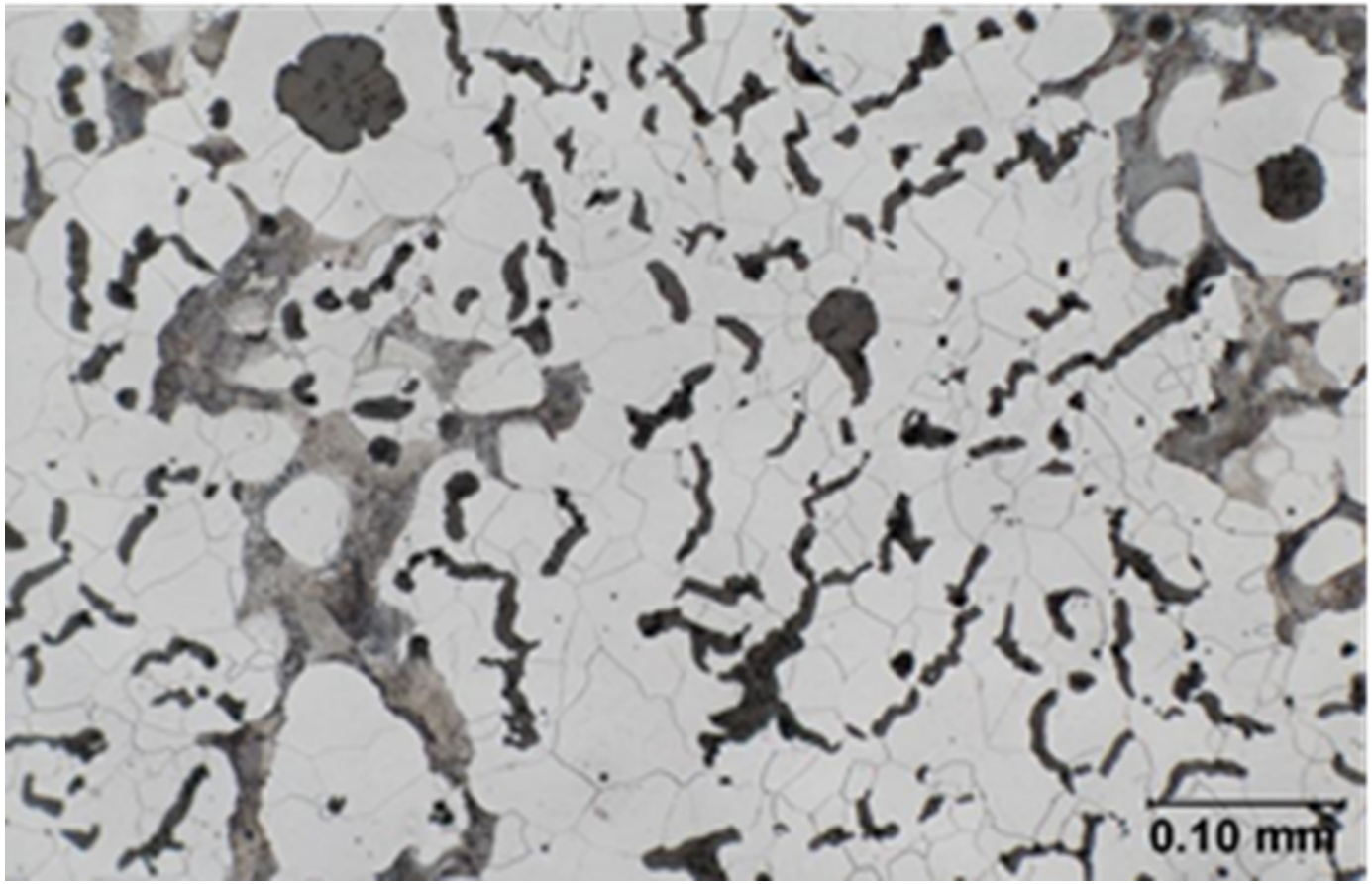


- Increased with increasing section size (increased with decreasing cooling rate)
- Increased with increasing pouring temperature

Surface Skin

- Lost foam “skin” is thinner than other processes at similar pouring temperatures
  - 0.01 to 0.13 mm for lost foam
  - 0.12 to 0.25 mm for phenolic-urethane [Boonmee, et al]
  - 0.13 to 0.39 mm for sodium silicate [Boonmee, et al]
  - 0.25 to 0.40 mm for green sand [SinterCast]

Bulk Microstructure



Typical Thick Section (polished and etched)

- 10-15% nodularity
- predominately ferrite plus some pearlite

Tensile Properties

Pouring Temperature	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Elastic Modulus (GPa)
1378°C	291	212	5.1	142
	289	214	5.5	143
1413°C	294	213	6.1	140
	288	216	5.4	142
1454°C	291	207	4.9	140
	288	204	3.6	144
average	290 +/- 3	211 +/- 5	5.1 +/- 0.8	142 +/- 2
Grade 250	250	175	3	
Grade 300	300	210	1.5	

Conclusions

- The lost foam casting process in conjunction with the SinterCast CG iron process control technology can be used to produce complex castings, such as cylinder blocks, in CG iron with a thinner “skin” than other processes.

- The skin in CG iron lost foam castings appeared to be caused by a solidification process and not reaction of molten metal with the foam or coating.

- Low cost EPS foam appeared to produce acceptable castings in CG iron, which would minimize production costs.

Acknowledgments

The authors would like to acknowledge the support for this study from the AFS/DOE Lost Foam Casting Consortium.

Further, this study would not have been possible without the support of Grede II LLC, Columbiana AL Division and SinterCast, Inc.

Thank-You

It is hoped that this research will encourage users to consider the use of the lost foam casting processing for the production of CG iron castings.

Thank-You !