Practical Applications of Compacted Graphite Iron

2 June 2005

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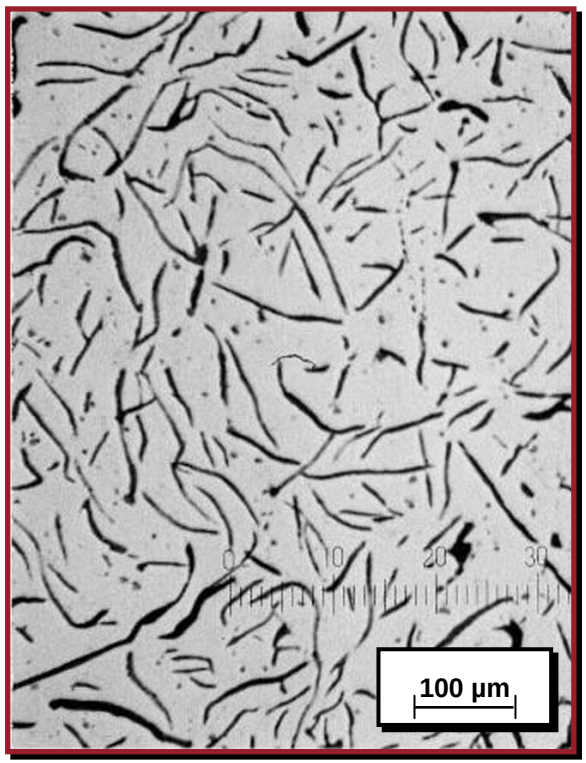
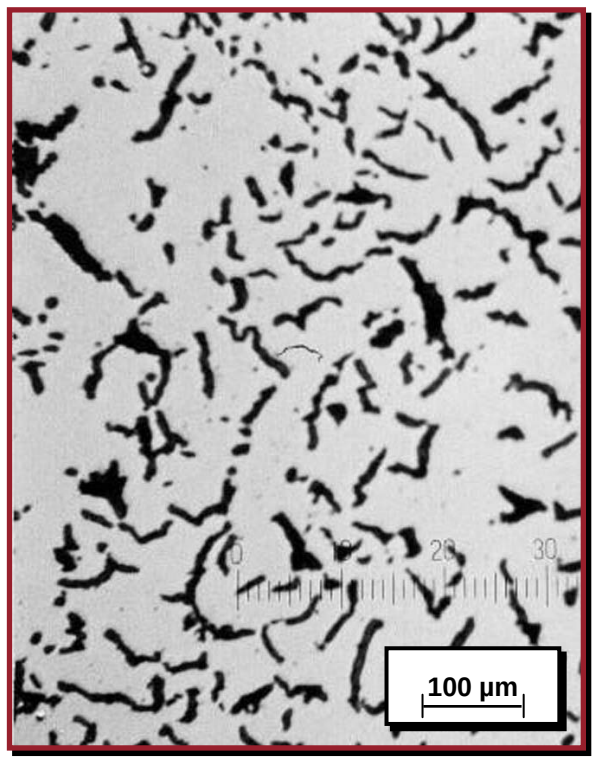
Supermetal CGI

Cast Iron Microstructures

Grey Iron



CGI



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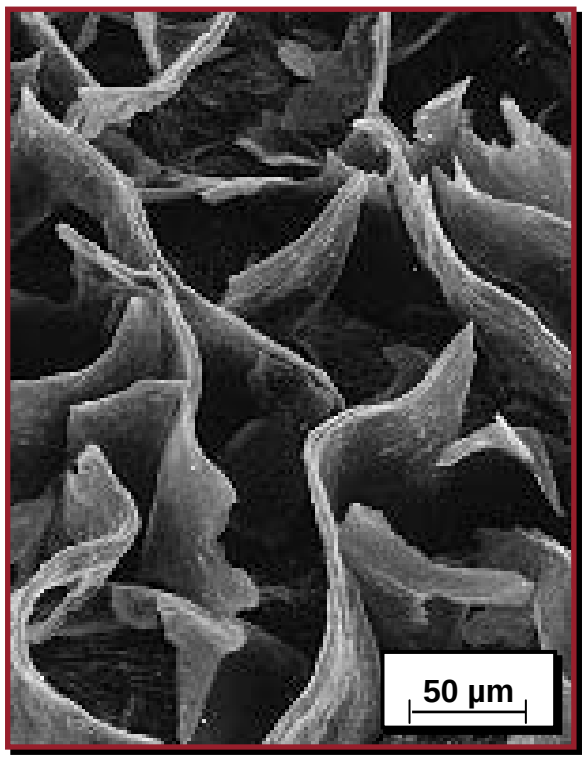
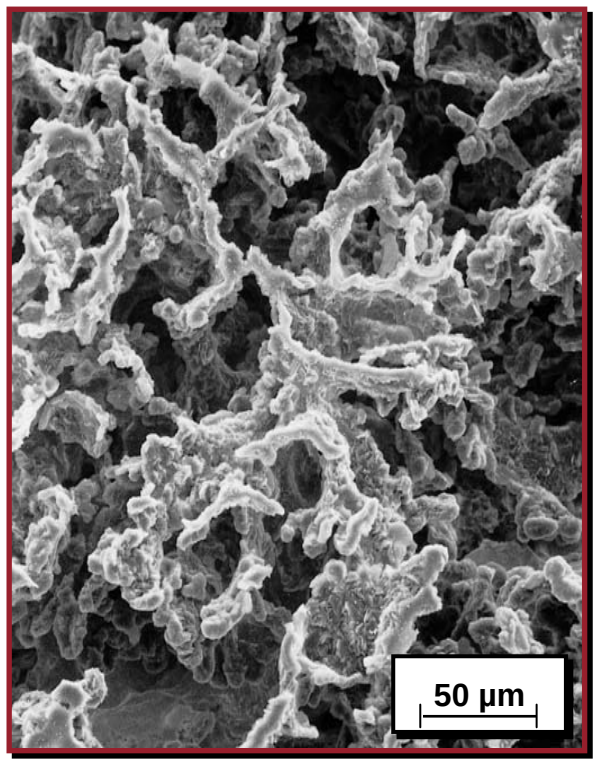


CGI



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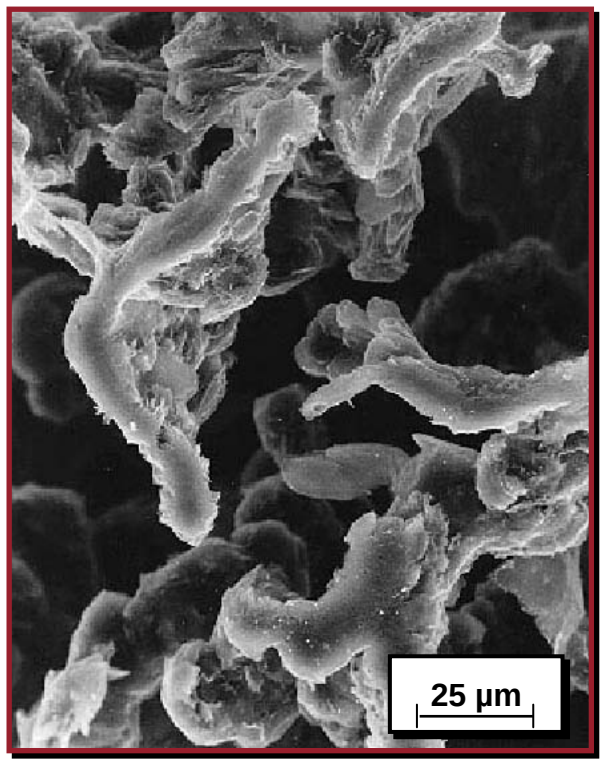

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CGI Properties

Property	Grey	CGI	Factor
Tensile Strength (MPa)	250	450	1.8
Elastic Modulus (GPa)	105	150	1.40
Fatigue: Push-Pull(MPa)	70	150	2.2
Thermal Conductivity (W/m-K)	47	37	0.8

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Market Status

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Prototype Production

Components, Foundries and OEMs

- 112,500 Prototype castings produced
  - 33,250 cylinder blocks
  - 5,000 cylinder heads
- 66 Foundries with SinterCast experience
- 55 Car, truck and engine Manufacturers
- 68 industry suppliers and research institutes

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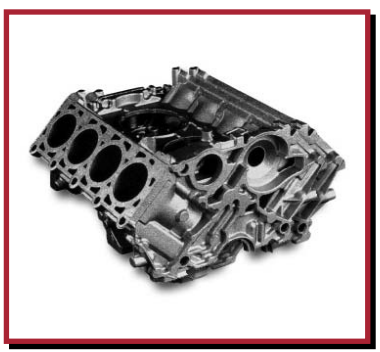
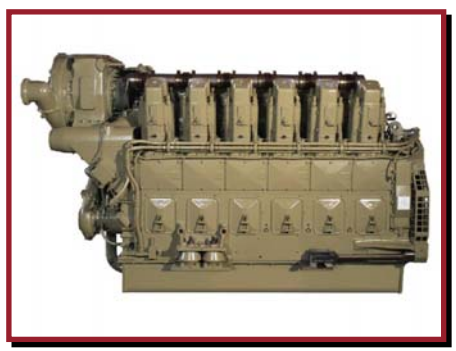
Series Production

- V - Diesel engines for Audi-Volkswagen and Ford-PSA
- High volume SOP for Hyundai-Kia V6 2006
- Engine components for Caterpillar
- Frames and heads for Rolls-Royce & General Electric
- Marine diesel piston rings for Daros
- Flywheels and clutch plates for Aston Martin





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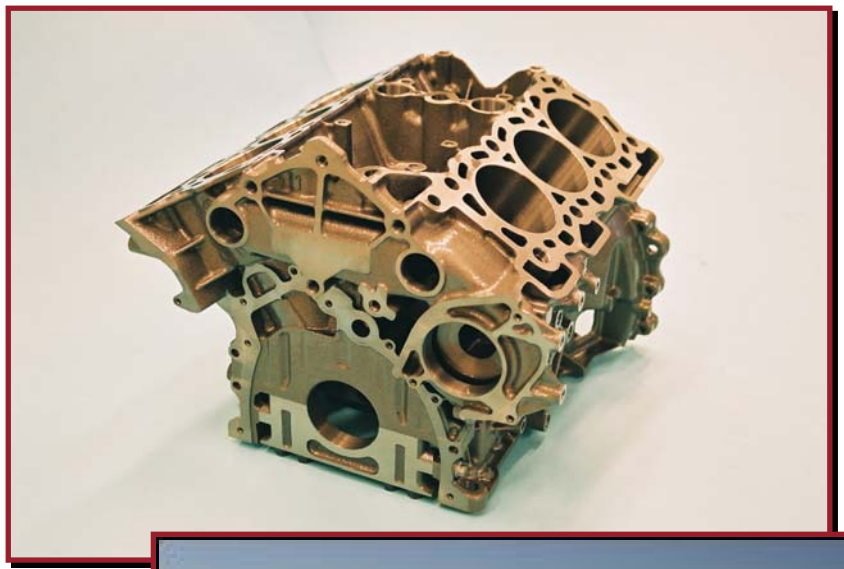
Series Production



Ford-PSA 2.7 litre V6

- Production start 2003
- Initial volume: 150,000 per year
- 207 horsepower, 440 Nm torque
- Specific performance: 57 kW/litre
- Jaguar, Land Rover, Ford, Mazda, PSA Peugeot-Citroën vehicles
- Euro IV compliant, Euro V capable

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Series Production

Audi 2.7 & 3.0 litre V6

- Production start 2003/04
- Total volume: 150,000 per year
- 2.7: 180 ps (50 kW/l) & 380 Nm
- 3.0: 233 ps (58 kW/l) & 450 Nm
- Audi & Volkswagen vehicles
- Euro IV compliant, Euro V capable

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Motorsport Production

Toyota Racing Development

- Production start 2004
  - Tupy, Brazil
- NASCAR Craftsman Series
- 650 horsepower, 5.8 Litre
- Spec. Perf: 83.5 kW/litre
- Weight: 89 kg
- Min. wall: 3.0 mm
- 28 sand cores

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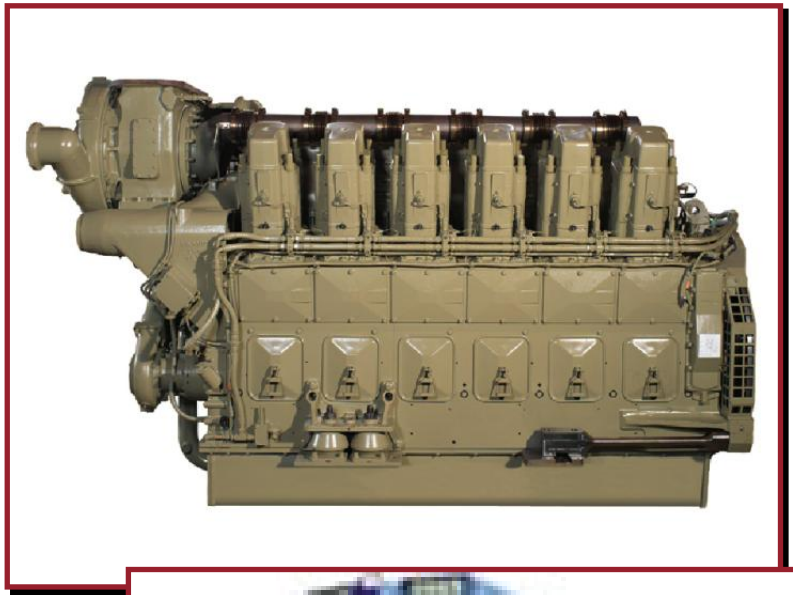
Industrial Power Generation



GE Transportation Systems

- Evolution Series “GEVO 12”
- V-12 Pot Head in CGI
- SOP Spring 2005
  - Motor Castings
- 40,000 Engine Eqvs/year
- Power Output: 4,400 ps
- EPA 2005 Compliant

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Market Development

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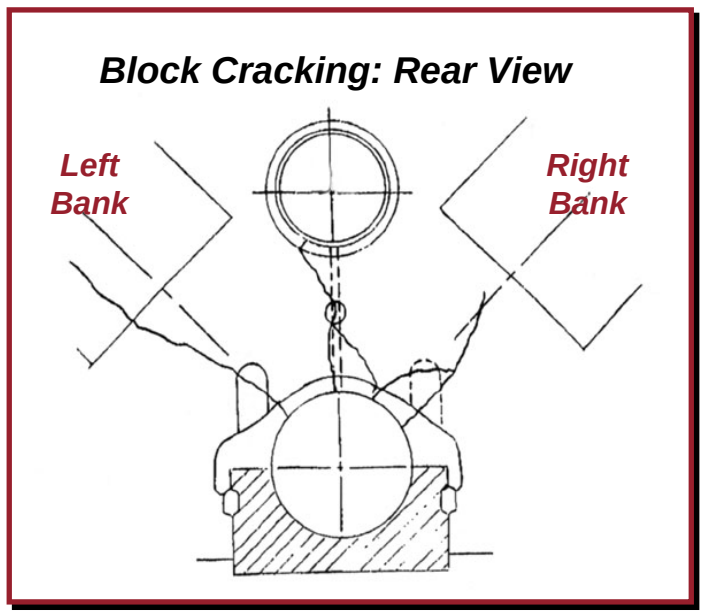
Market Development

Current & Future Trends

- Increased peak firing pressures
  - 1997: 135 bar and 40 kW/litre
  - 1999: 160 bar and 50 kW/litre
  - 2004: 170 bar and 60 kW/litre
  - 2006: 190 bar and 66 kW/litre
- Target: 100 kW/litre
- Fatigue resistance of main bearing
- Overall package size and weight



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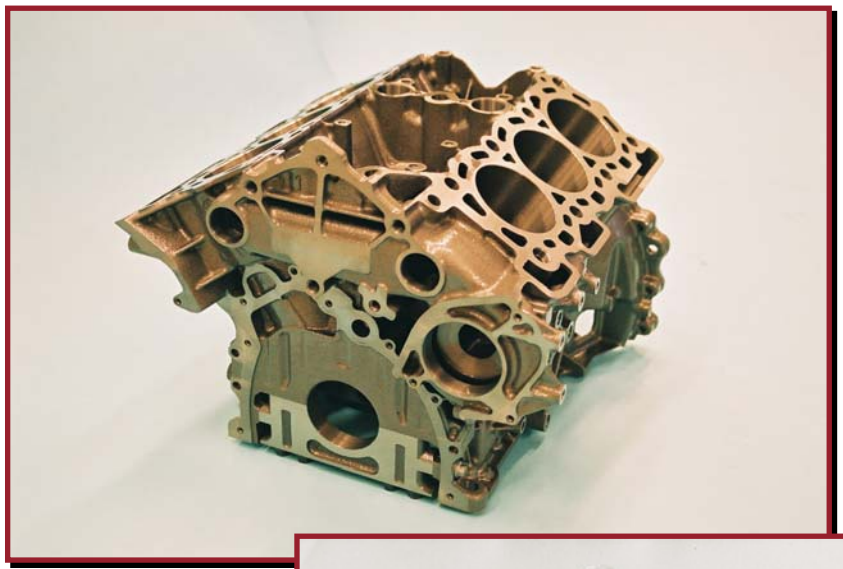
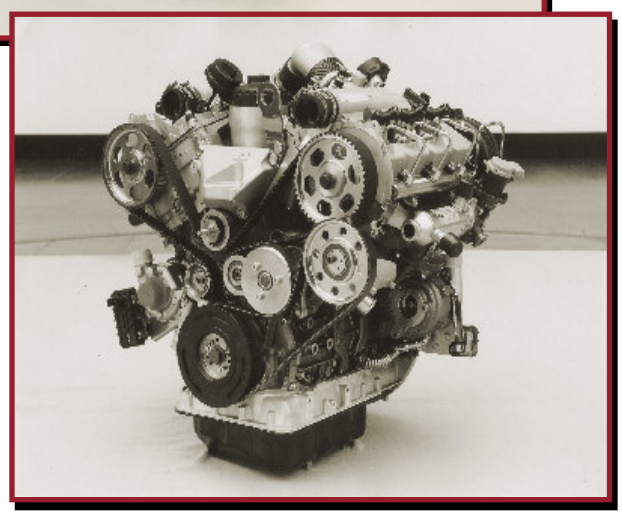
CGI vs. Aluminium





Ford-PSA 2.7 litre V6

- Compared to Aluminium:
  - Same assembled weight
  - Smaller package
  - Higher specific performance
  - Lower oil consumption
  - More growth potential
  - Quieter
  - Lower Cost
  - More recyclable

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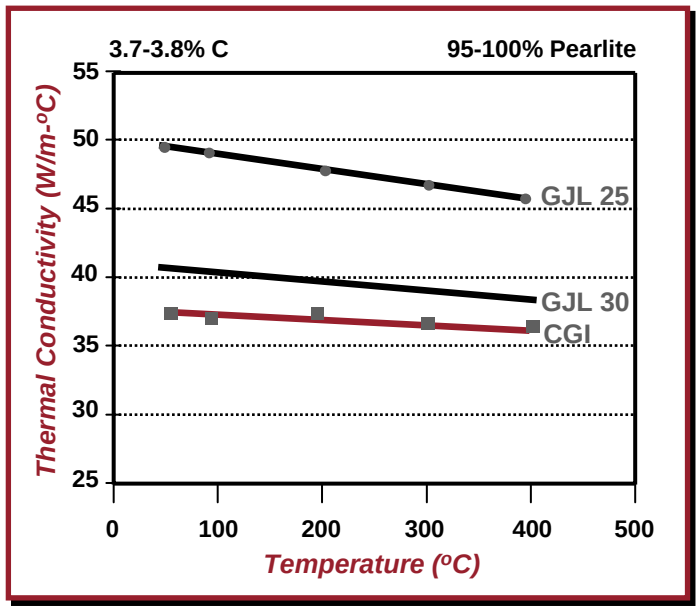
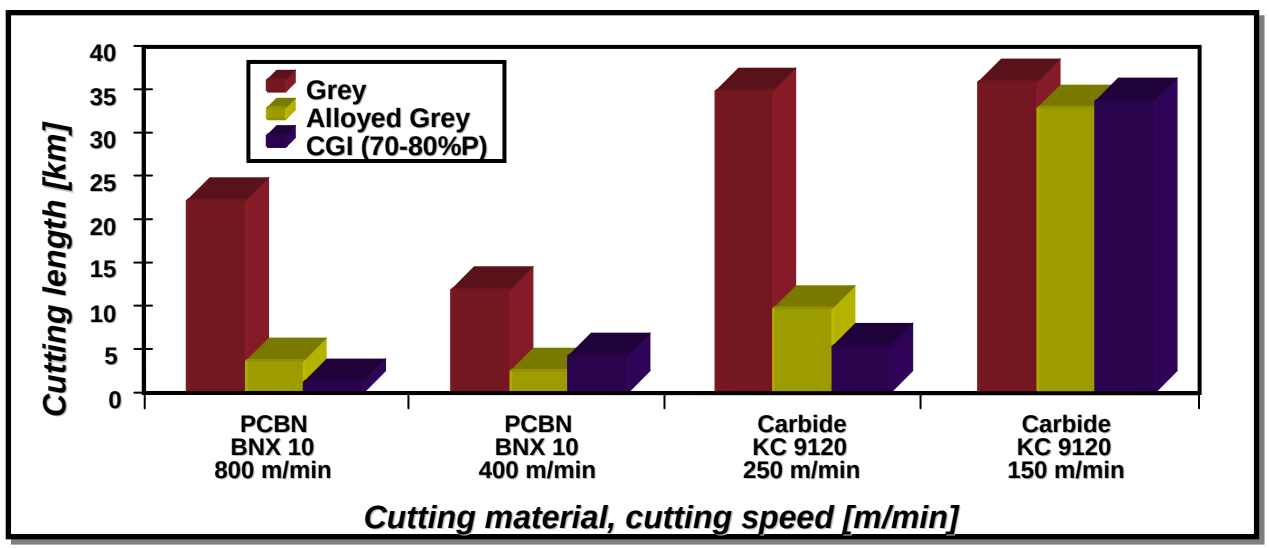
CGI vs. Alloyed Grey Iron



CGI vs. GJL 27+ or GJL 30

- Castability
- Thermal Conductivity
- Machinability
- Tensile: +20% vs. +80%
- Modulus: +10% vs. +45%
- Fatigue: +20% vs. +100%



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Market Development

Product Applications – “The Five Waves”

- Step 1: V-diesel cylinder blocks in Europe
- Step 2: Commercial vehicle cylinder blocks and heads

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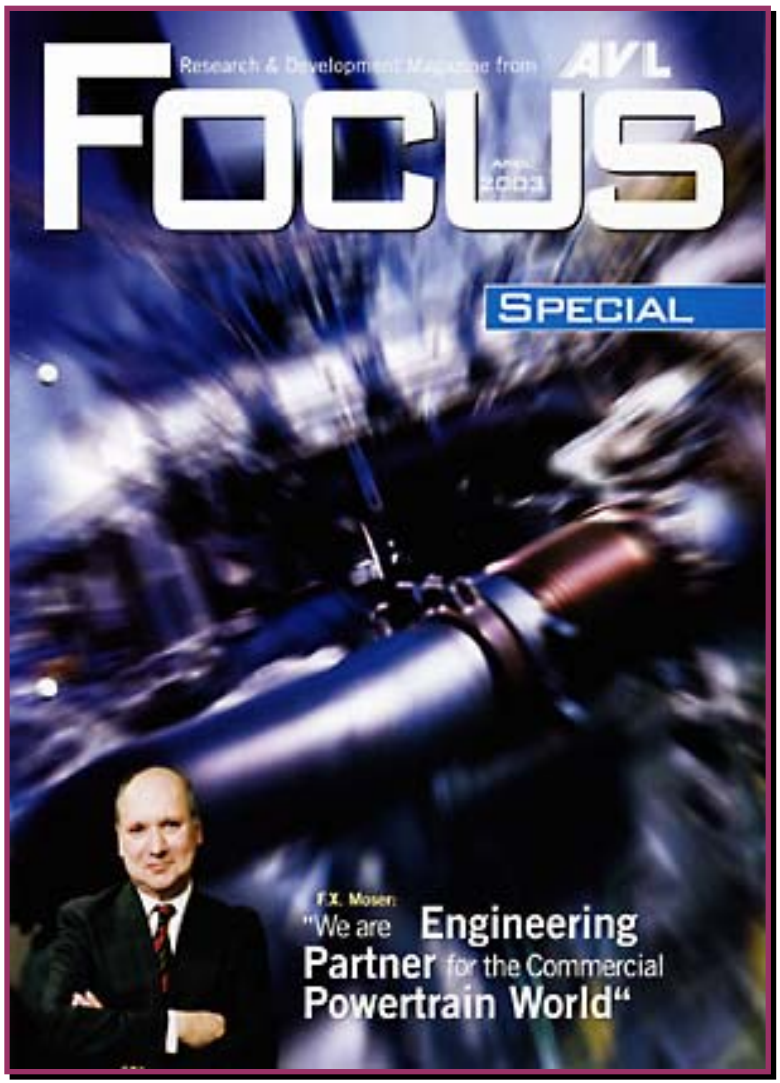
Step 2: Commercial Vehicles



"The engine of 2007 will have the same basic design as today. There will be many improvements, such as more intelligent detail designs and alternative materials will be used for the cylinder block and head. ***For example, Compacted Graphite Iron will replace grey cast iron.****"*

Dr. Franz Zieher
Head of Design and Calculation
Commercial Powertrain Systems
AVL List

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Market Development

Product Applications – “The Five Waves”

- Step 1: V-diesel cylinder blocks in Europe
- Step 2: Commercial vehicle cylinder blocks and heads
- Step 3: In-line diesel cylinder blocks in Europe
- Step 4: Diesels in America, and Beyond

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US Diesel Penetration Predictions

Information Source	Penetration	Year
JD Power - LMC	9%	2009
Auto Technology Res Gp	12%	2009
International - Navistar	25%	2010
Bosch Automotive	20%	2014
British Petroleum BP	18%	2015
JD Power - LMC	16%	2015
United States EPA	40%	2020

Ricardo predicts 6% year-on-year growth from 2010

Global: 14% 1999, 18% 2004, 23% 2010 (Bosch)

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Market Development

Product Applications – “The Five Waves”

- Step 1: V-diesel cylinder blocks in Europe
- Step 2: Commercial vehicle cylinder blocks and heads
- Step 3: In-line diesel cylinder blocks in Europe
- Step 4: Diesels in America, and Beyond
- Step 5: Petrol engine cylinder blocks
- Potential Step: Diesel engine cylinder heads
- Support Steps: Non-automotive
  Non-block & head

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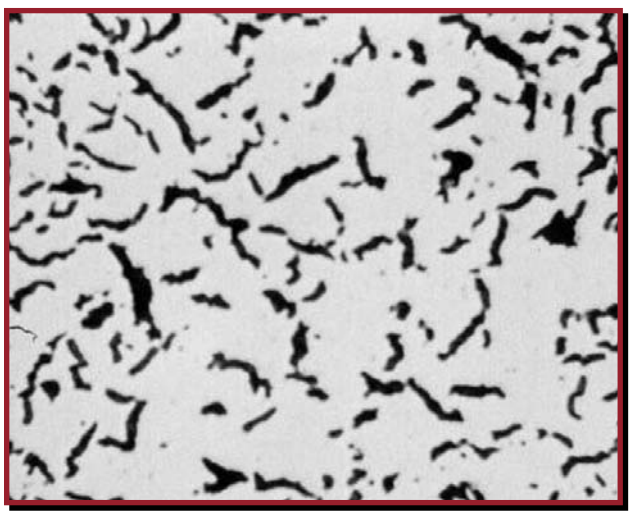
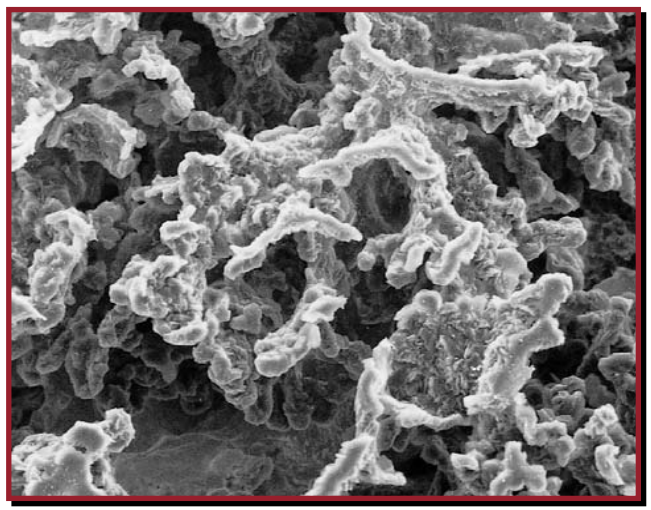
Market Development

Conclusion

- The need for CGI has been established
- The foundry technology is ready
- The manufacturing technology is ready
- Successful high volume references in each sector





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