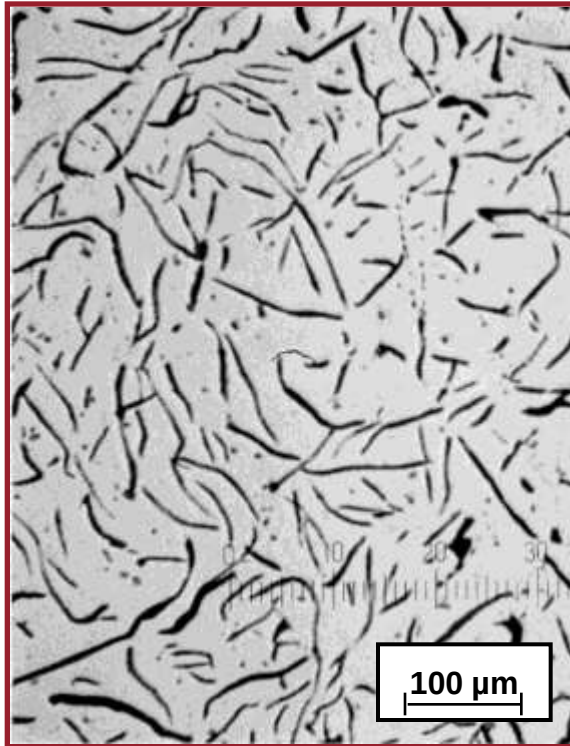


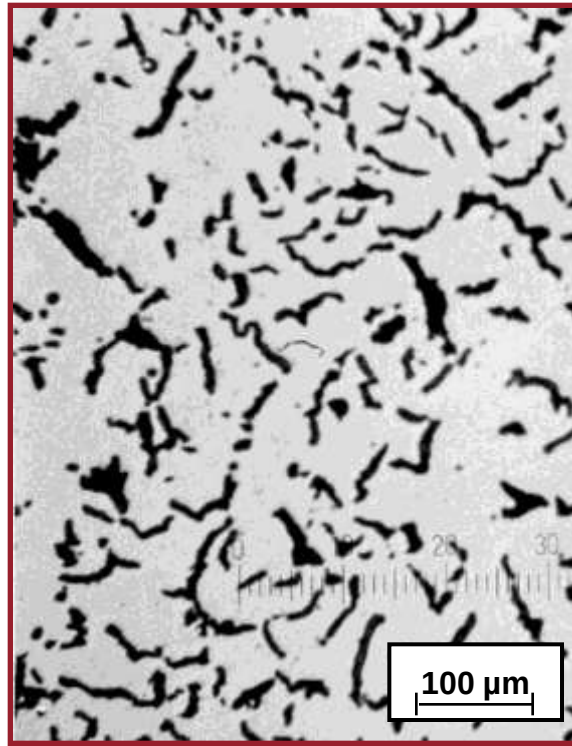
# Microstructures, Properties and Engine Benefits

# Cast Iron Graphite Microstructures

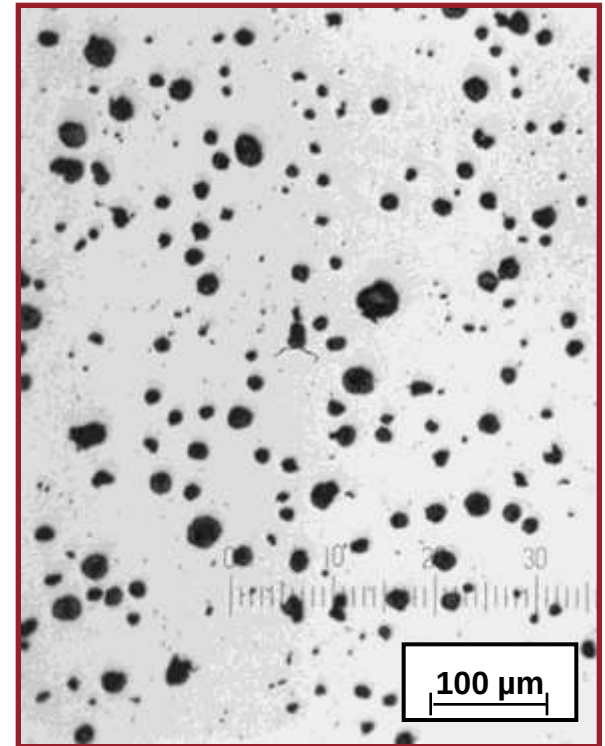
**Grey**



**CGI**

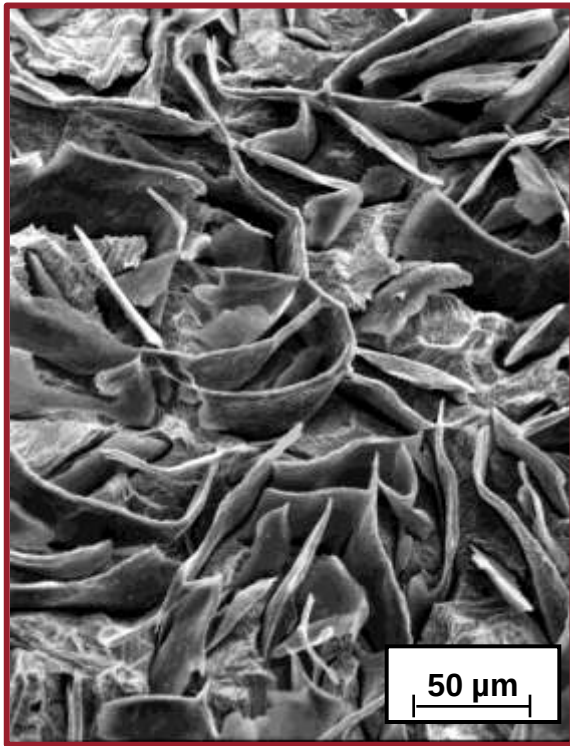


**Ductile**

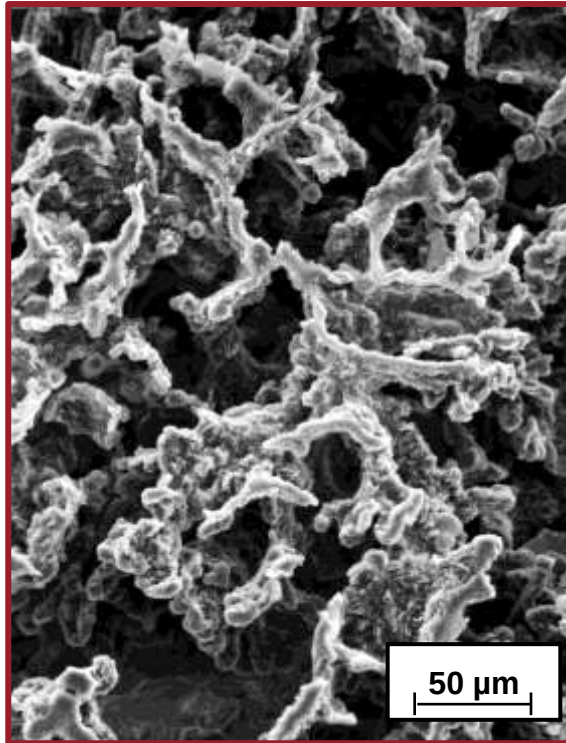


# Cast Iron Graphite Microstructures

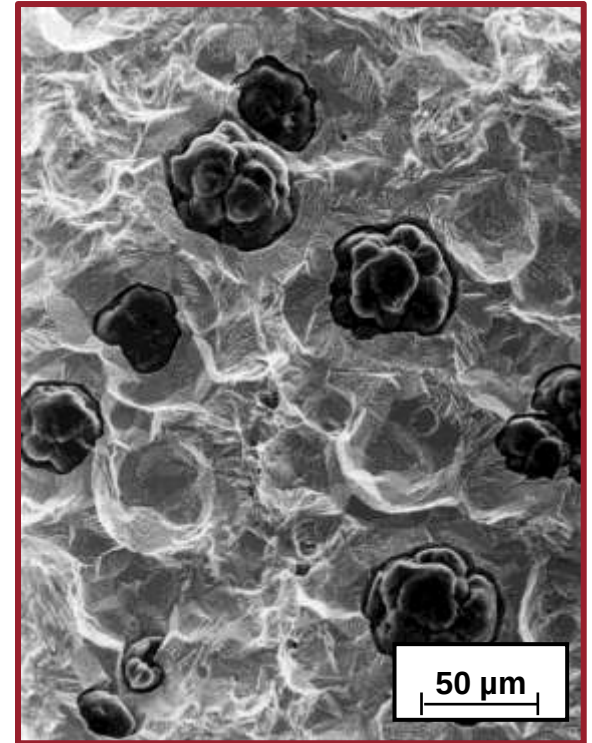
**Grey**



**CGI**



**Ductile**

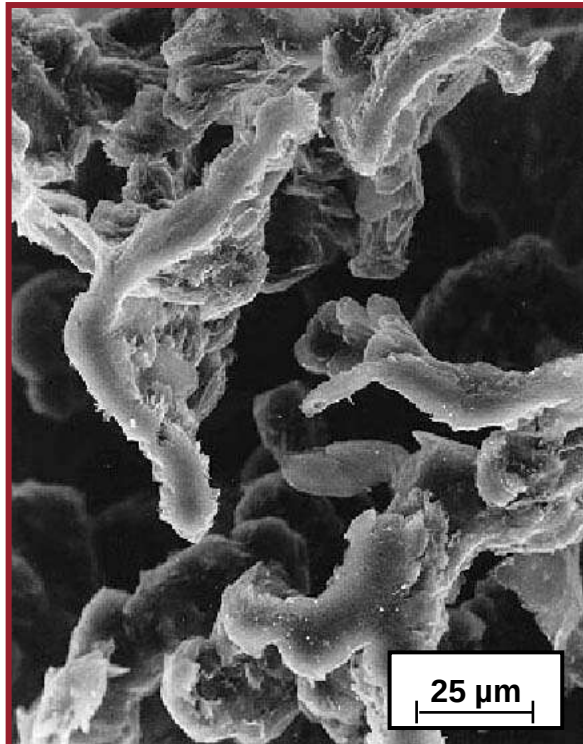


# Cast Iron Graphite Microstructures

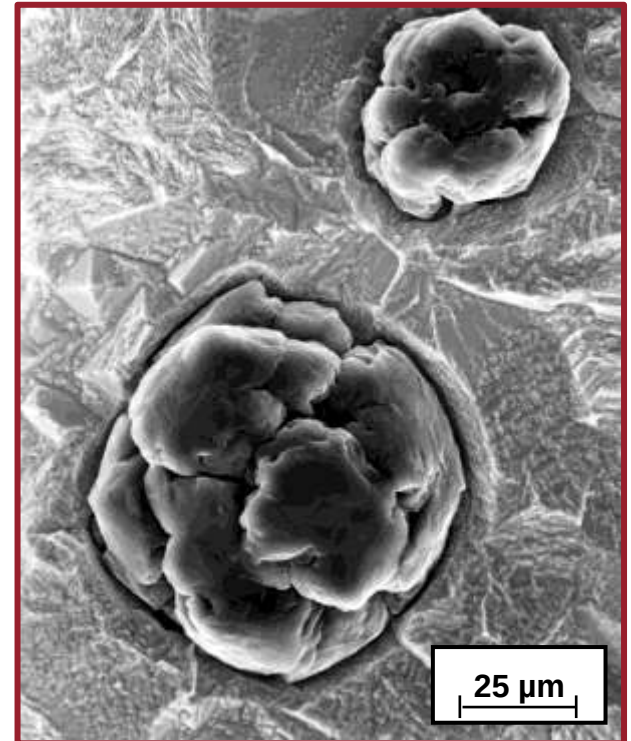
**Grey**



**CGI**

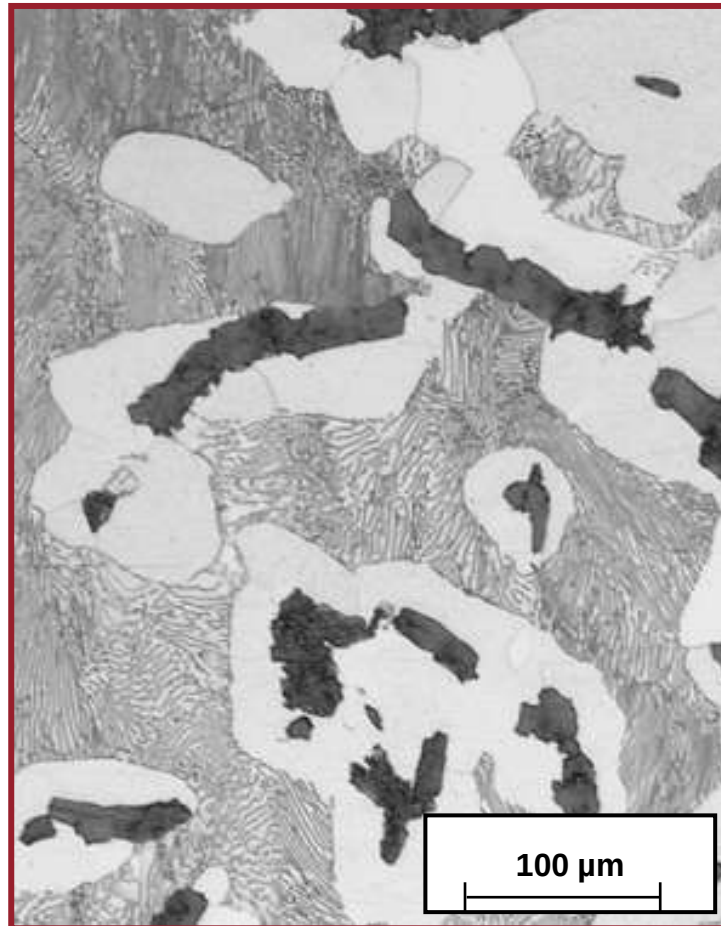


**Ductile**



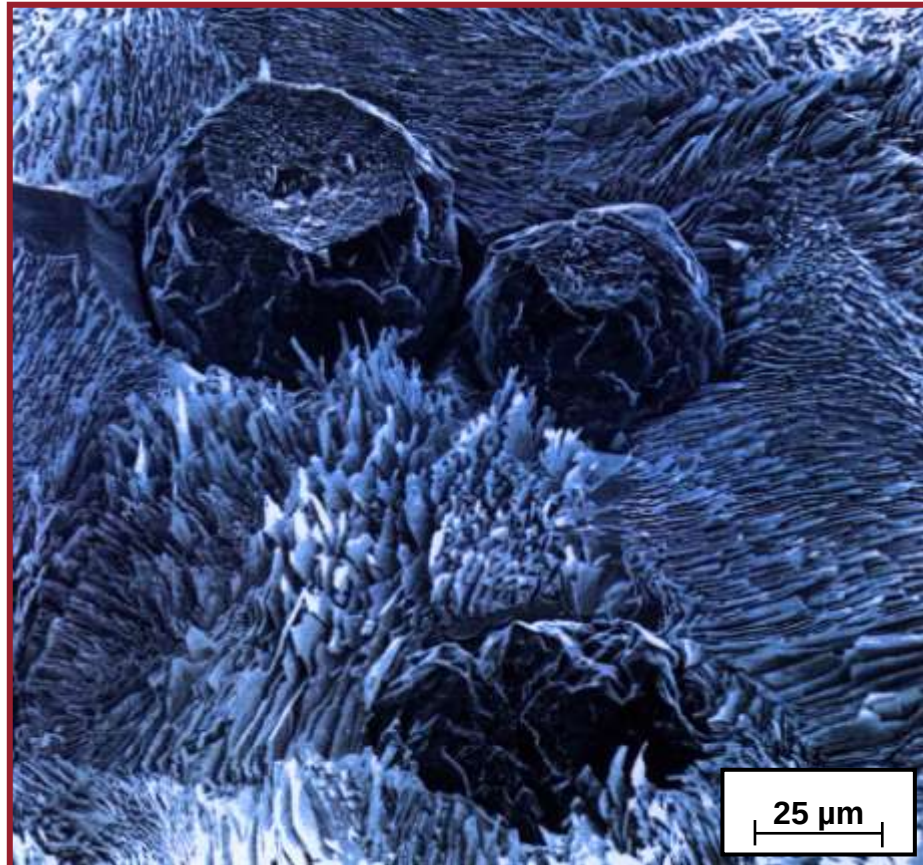
# Cast Iron Microstructures

## Ferrite or Pearlite?



# Cast Iron Microstructures

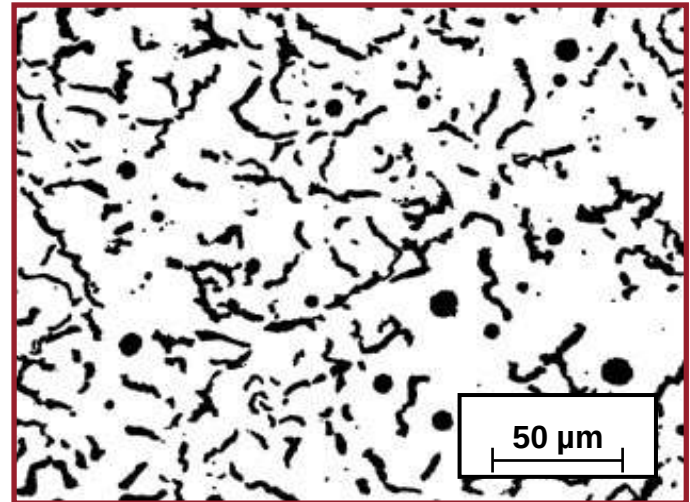
## Ferrite or Pearlite?



# CGI Microstructure Specification

## For Optimal Castability, Machinability and Thermal Conductivity

- 0-20% nodularity in performance-critical sections
- No free flake graphite
  - Flake skin control
- Uniform graphite distribution
- Pearlite as desired (>90%)
- Machinability
  - Trace carbides
  - <0.02% Titanium

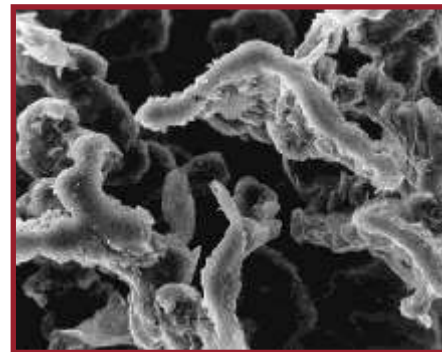
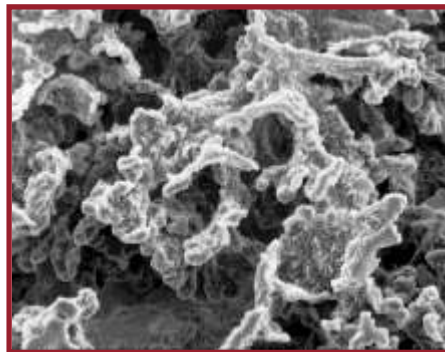
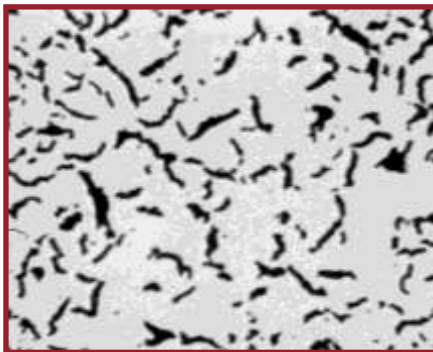


10% Nodularity

# CGI Microstructure Specification

## International Standards

- ISO 16112 (2008; 2017)
- European Norm EN 16079 (2011)
- SAE J1887 (2002)
- ASTM A842 (1997)
- JIS G 5505 (2013)
- Chinese GB/T 26655-2011
  - JB3829-1999



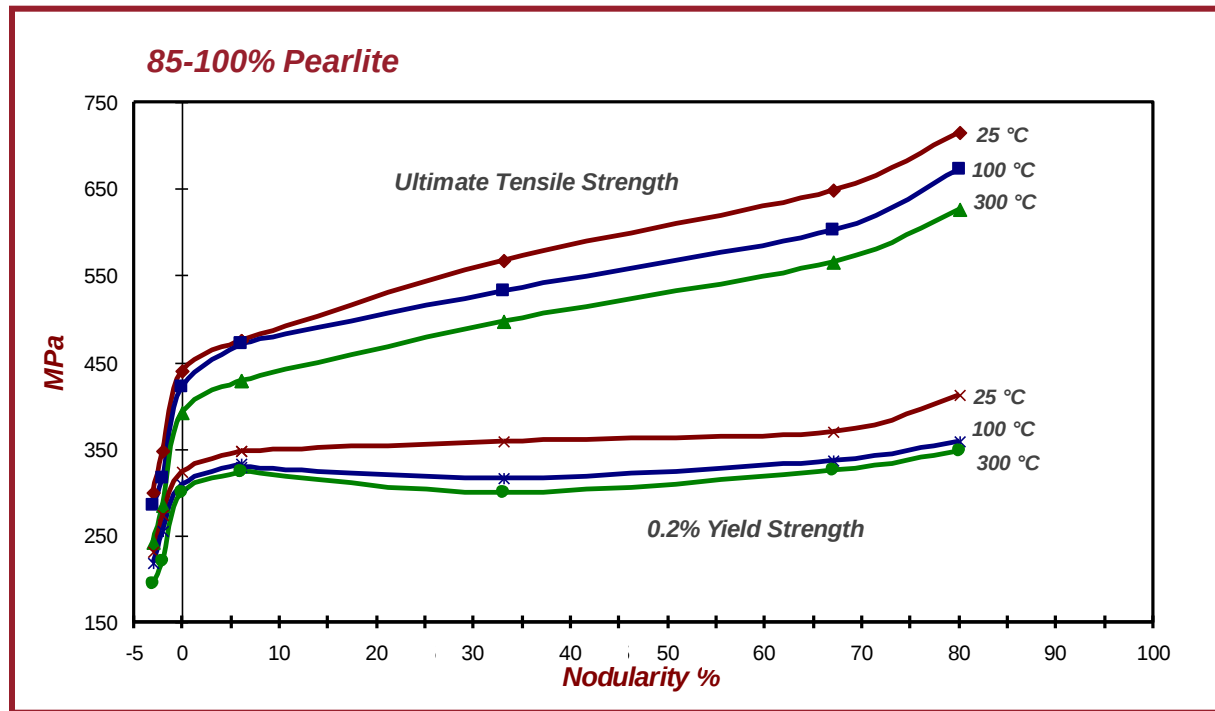
# Mechanical and Physical Properties

## CGI vs. Grey Iron

| Property                                    | Grey   | CGI    | Factor |
|---------------------------------------------|--------|--------|--------|
| Tensile Strength (MPa)                      | 250    | 450    | 1.8    |
| Elastic Modulus (GPa)                       | 105    | 145    | 1.4    |
| Fatigue, Push-Pull (MPa)                    | 75     | 140    | 1.9    |
| Elongation (%)                              | 0.1    | 1.5    | 15     |
| Thermal Conductivity (W/m-K)                | 47     | 37     | 0.8    |
| Poisson's Ratio                             | 0.27   | 0.26   | 1.0    |
| Density (g/cc)                              | 7.2    | 7.1    | 1.0    |
| T Expansion, 20-400 C ( $\mu\text{m/m-K}$ ) | 11-13  | 11-13  | 1.0    |
| Specific Heat, 100 C (J/g-K)                | 0.45   | 0.45   | 1.0    |
| Enthalpy, 20-200 C (J/kg)                   | 80,000 | 80,000 | 1.0    |

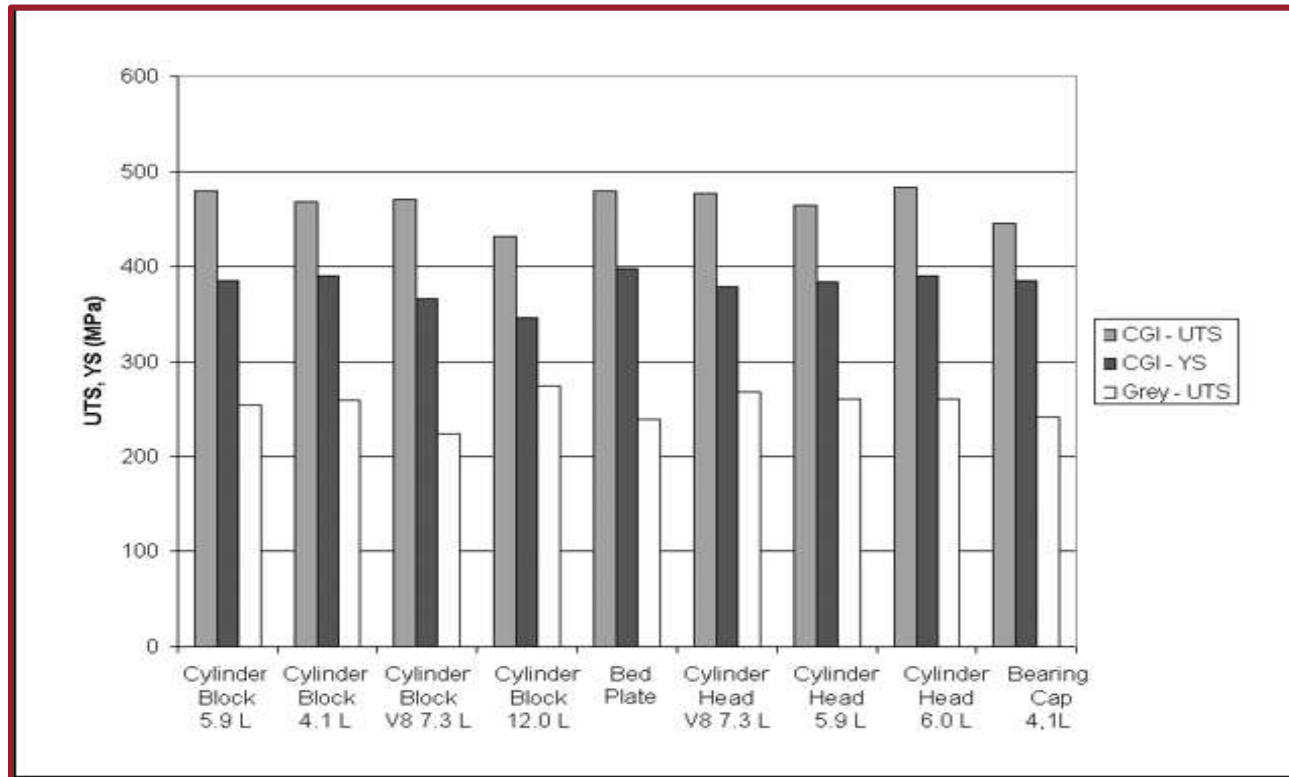
# Mechanical and Physical Properties

## Ultimate Tensile and 0.2% Yield Strength



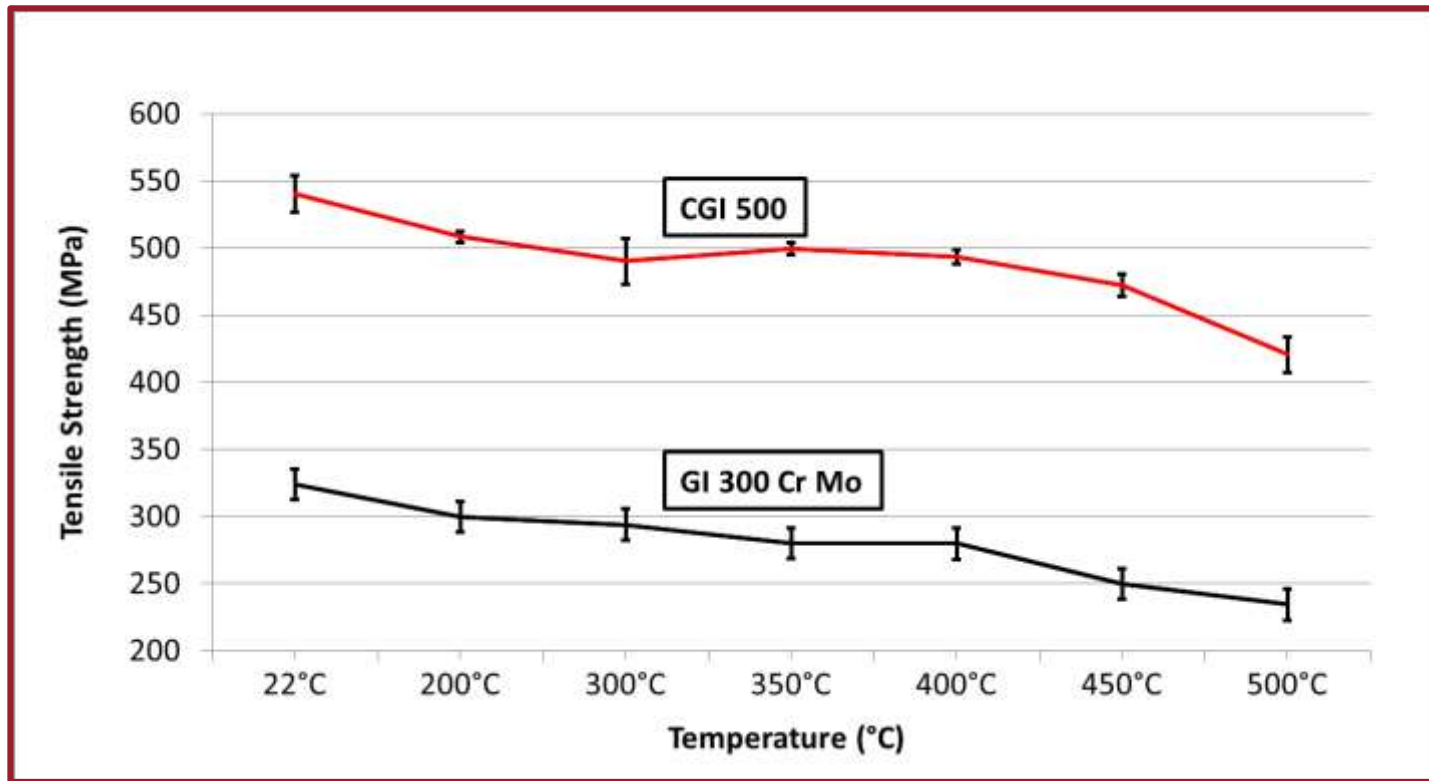
# Mechanical and Physical Properties

## Tensile and Yield Strength (CGI vs. Grey Iron)



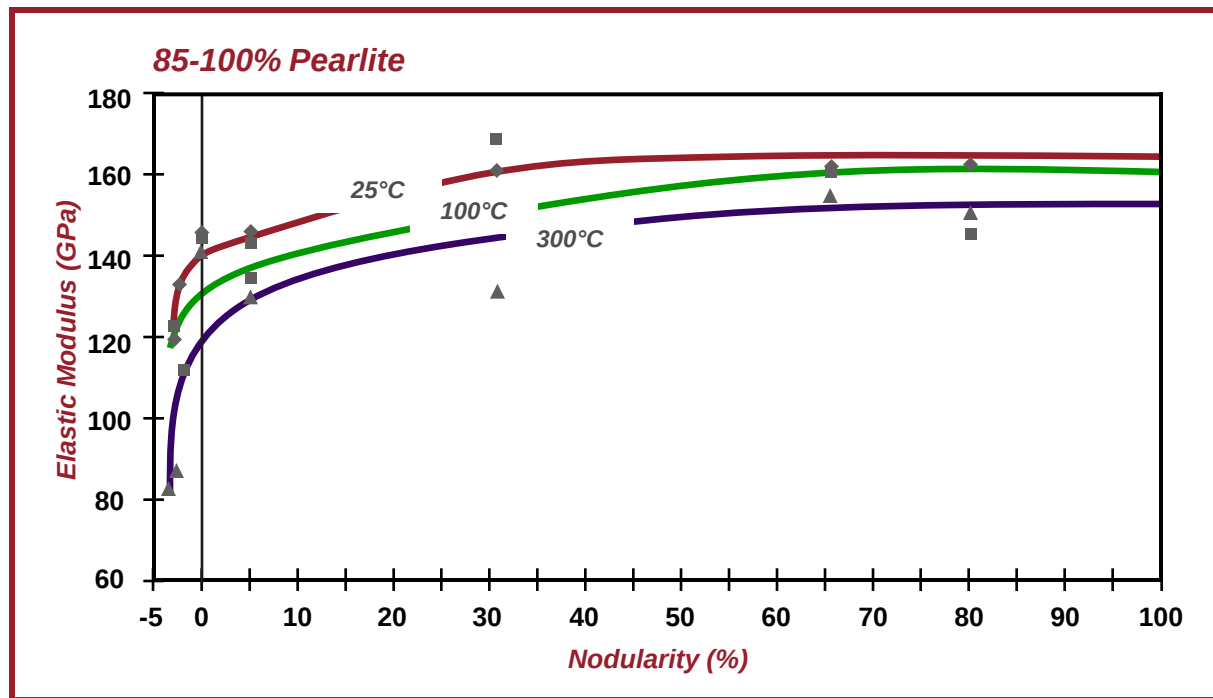
# Mechanical and Physical Properties

## Ultimate Tensile Strength (CGI vs. Grey Iron)



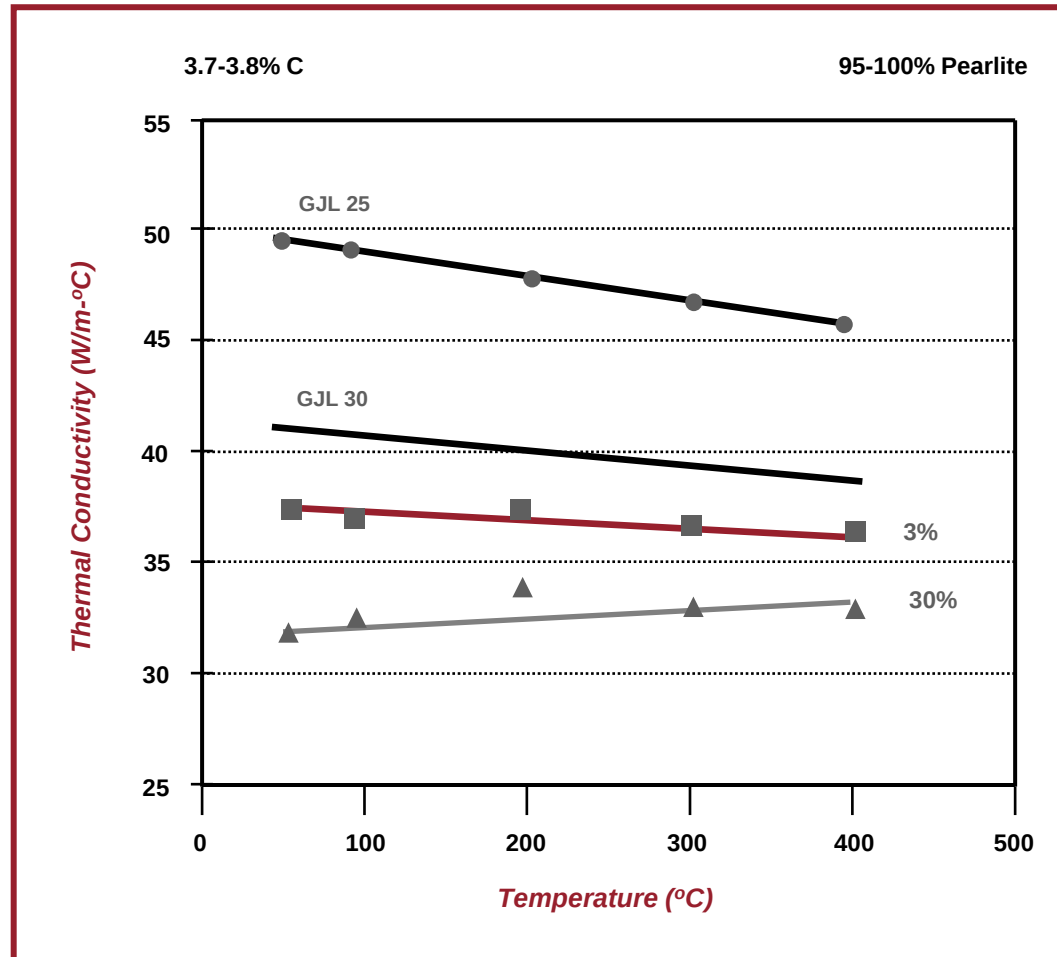
# Mechanical and Physical Properties

## Elastic Modulus



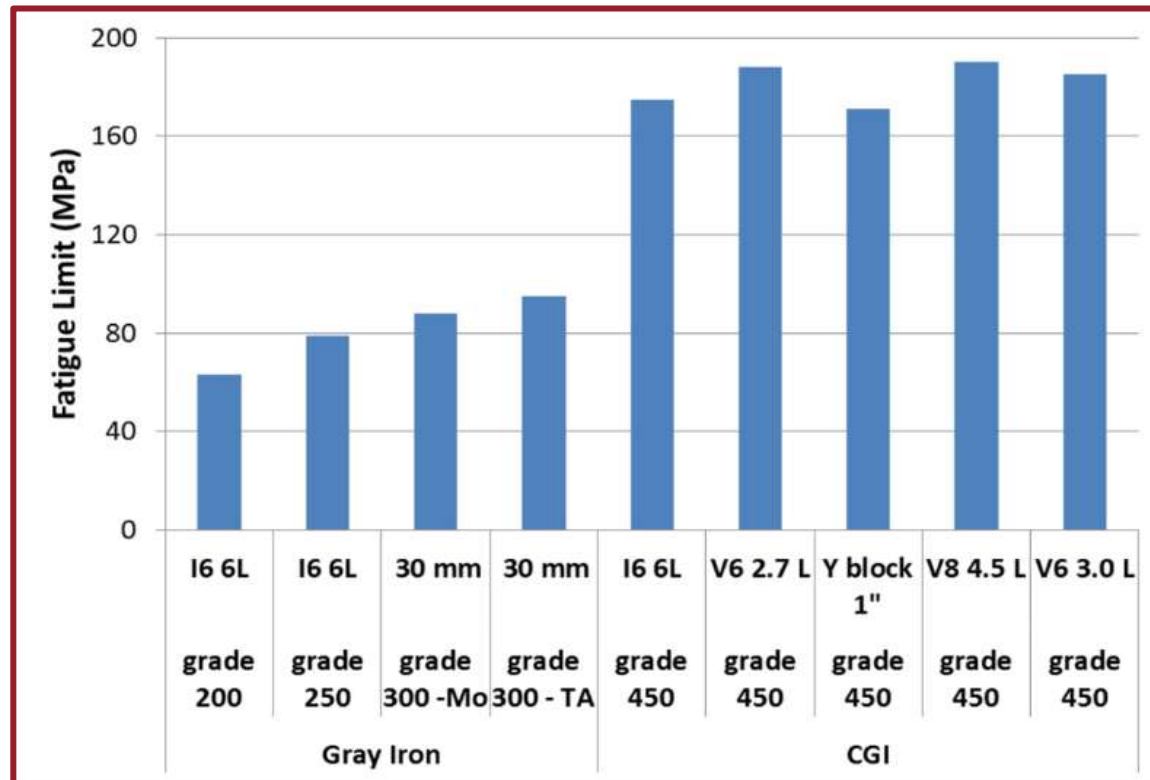
# Mechanical and Physical Properties

## Thermal Conductivity



# Mechanical and Physical Properties

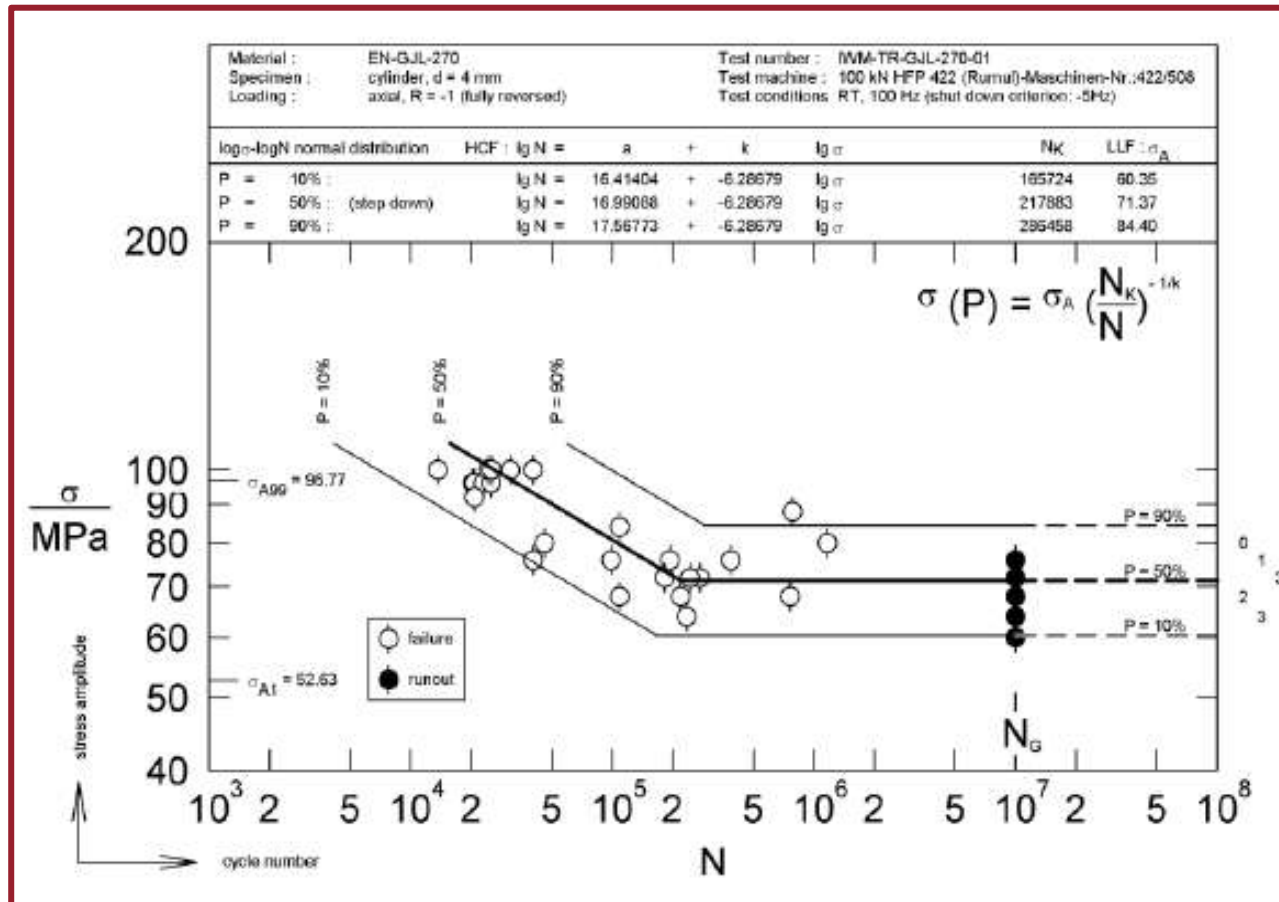
## Tension – Compression Fatigue (CGI vs. Grey Iron)



Courtesy Tupy

# Mechanical and Physical Properties

## Tension-Compression Fatigue (CGI vs. Grey Iron)



### Grey Iron

UTS = 270-300 MPa

R = -1

T = 20°C

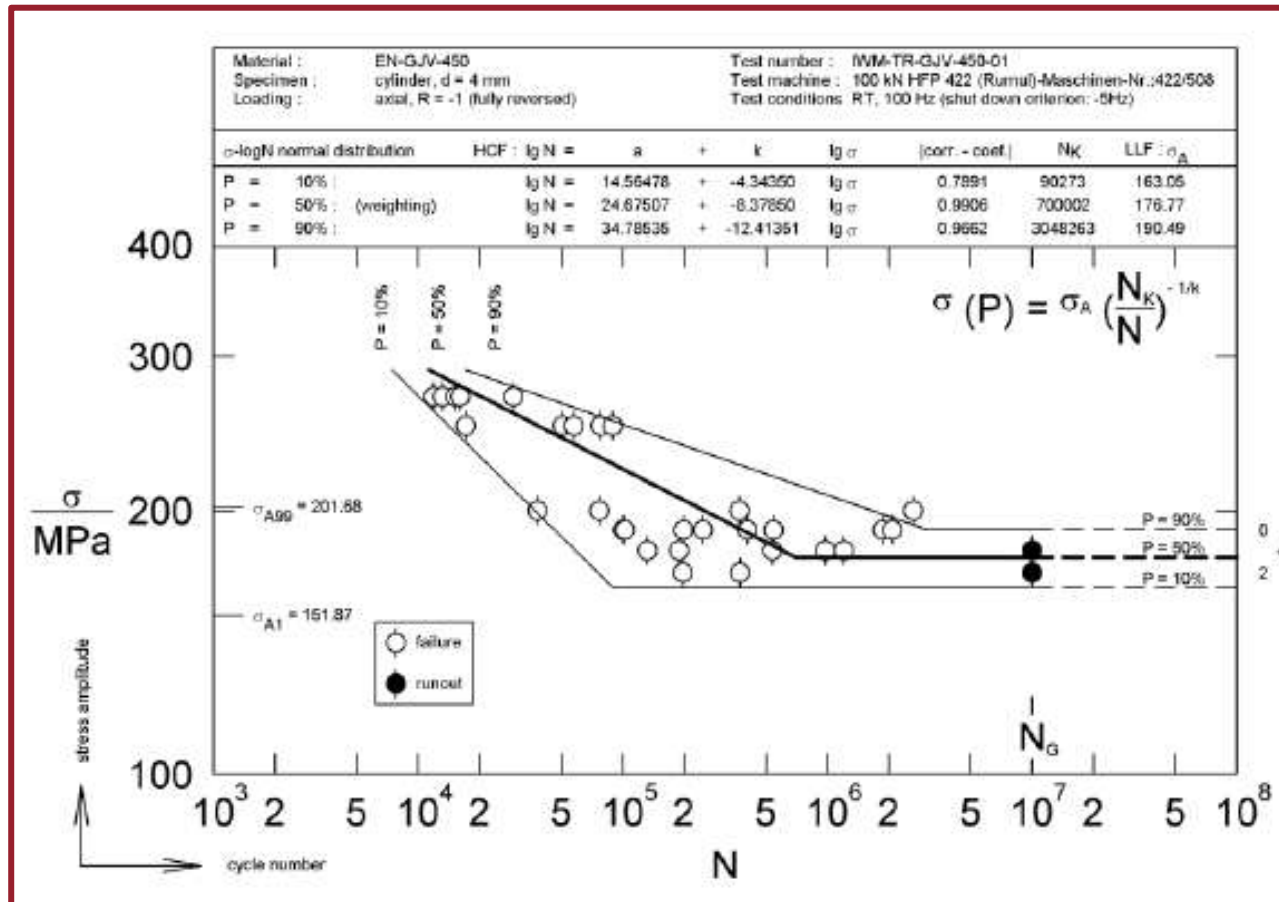
P<sub>50</sub> = 71 MPa

T. Rausch, IWM RWTH Aachen, 2010

**SinterCast**  
— Supermetal CGI —

# Mechanical and Physical Properties

## Tension-Compression Fatigue (CGI vs. Grey Iron)



### CGI

UTS = 450-500 MPa

R = -1

T = 20°C

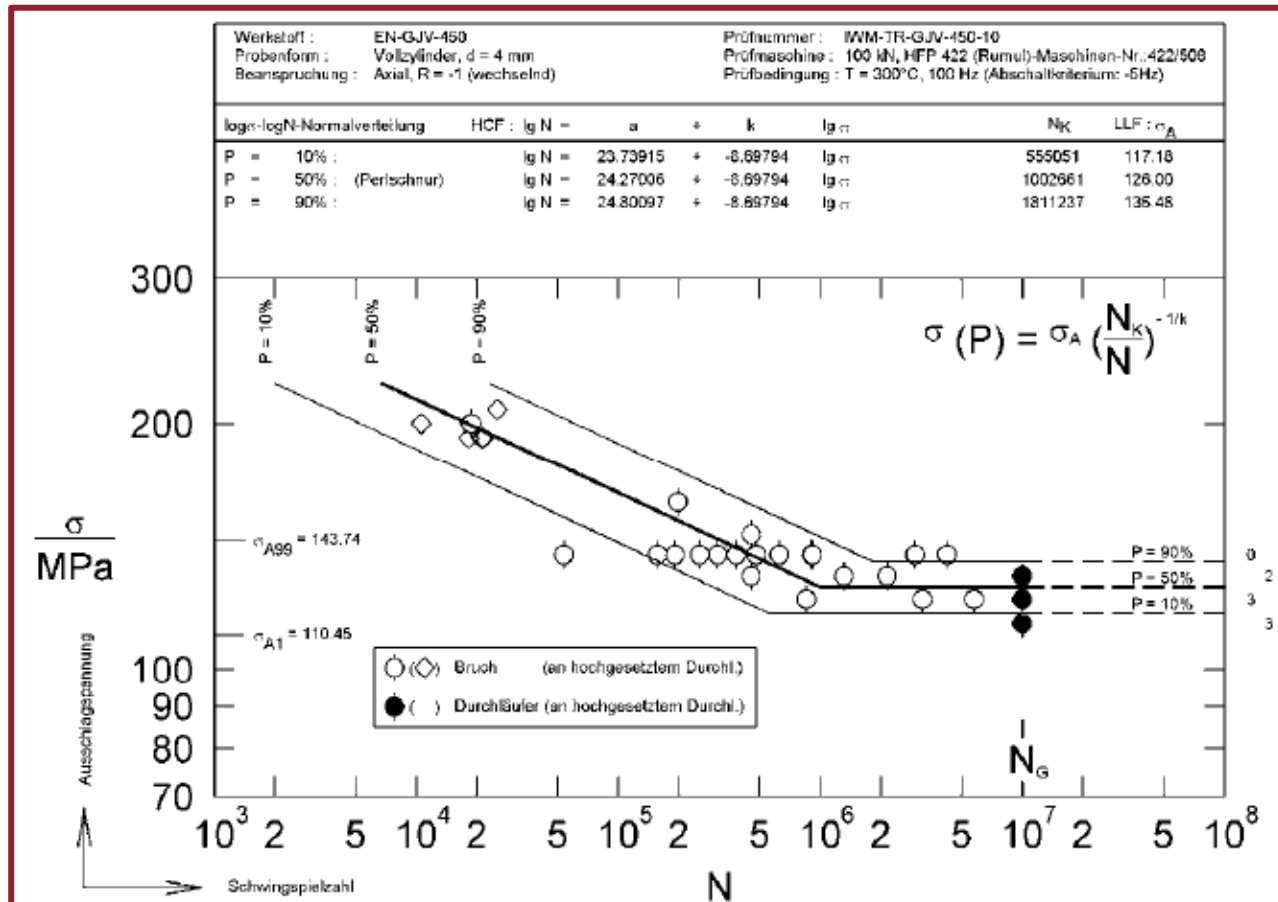
P<sub>50</sub> = 177 MPa

T. Rausch, IWM RWTH Aachen, 2010

**SinterCast**  
— Supermetal CGI —

# Mechanical and Physical Properties

## Tension-Compression Fatigue (CGI vs. Grey Iron)



### CGI

UTS = 450-500 MPa

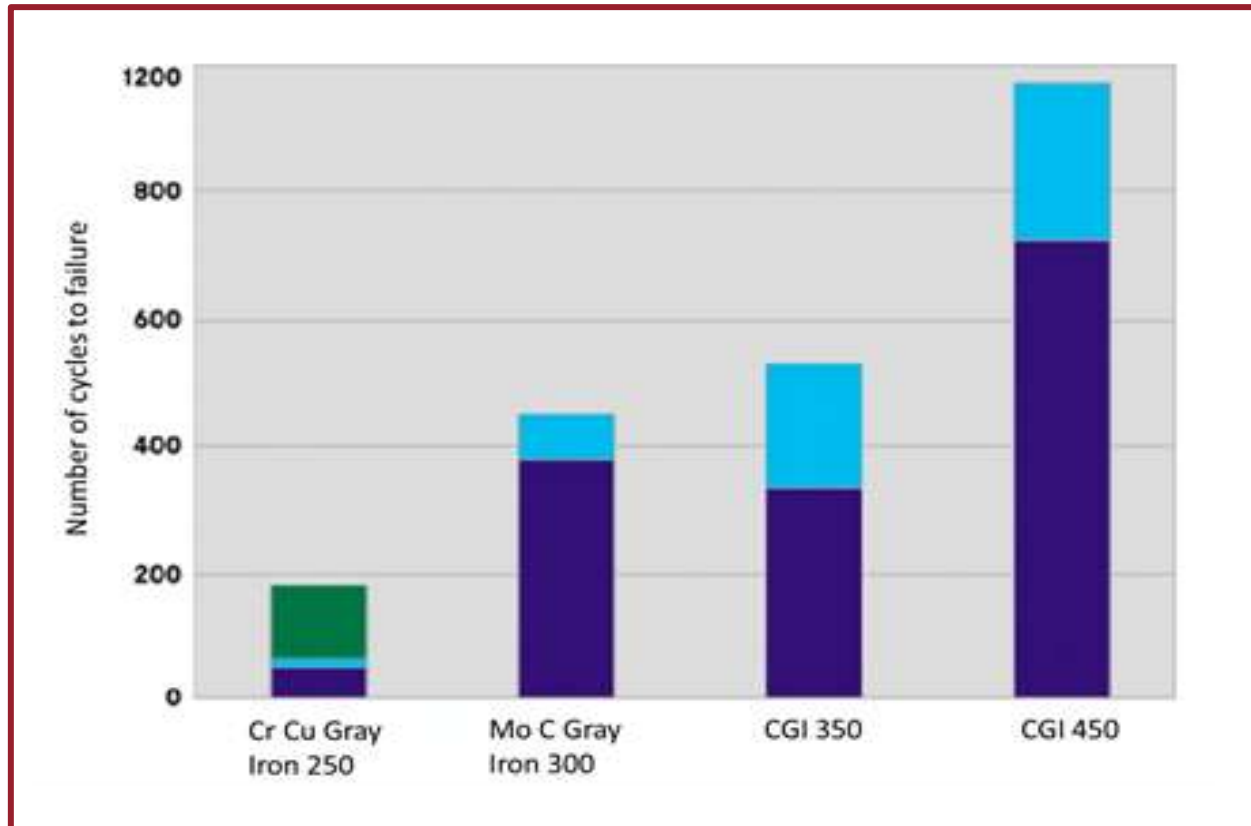
R = -1

T = 300°C

P<sub>50</sub> = 126 MPa

# Mechanical and Physical Properties

## AVL Thermal Fatigue Test (CGI vs. Grey Iron)



*Constrained Tension-Compression; 50 - 420°C*

**SinterCast**  
— Supermetal CGI —

# Engine Advantages

# Engine Advantages

## CGI Engine Benefits

- Weight reduction (10~20%)
  - Minimum wall thickness 3.0 mm
- Package size reduction
  - 5% height and width, 10~20% length
  - Downsizing & power-up (12L replaces 15L; 300 kg weight reduction)
- Increased durability and performance (10~20%)
- NVH Reduction (0.5~1.5 dB)
- Cylinder bore distortion (20~30%)
  - Emissions, oil consumption, friction losses and Power-up
- Design Advantages
  - Fracture split main bearings
  - 1.2d instead of 1.5d (1.9d for aluminium)