Aalto University

Cast Materials

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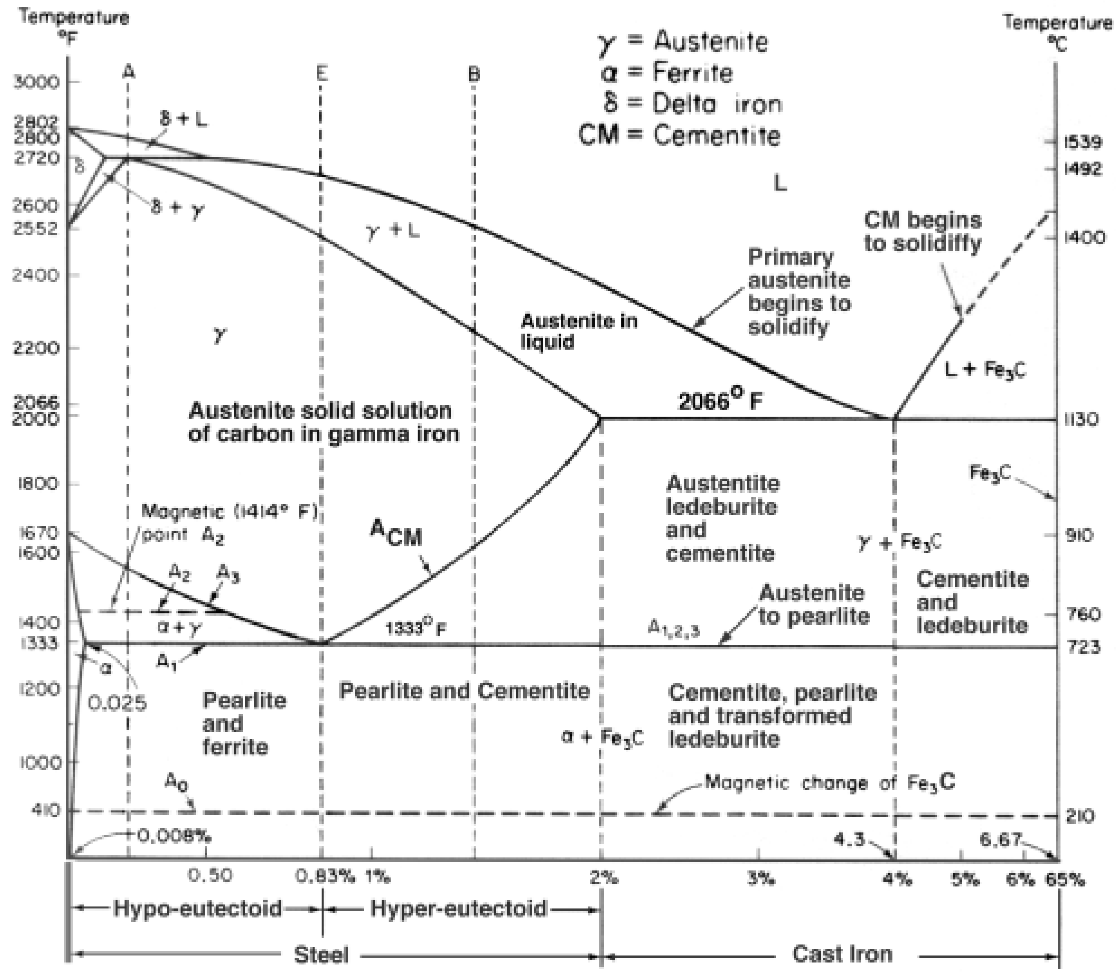
Overview

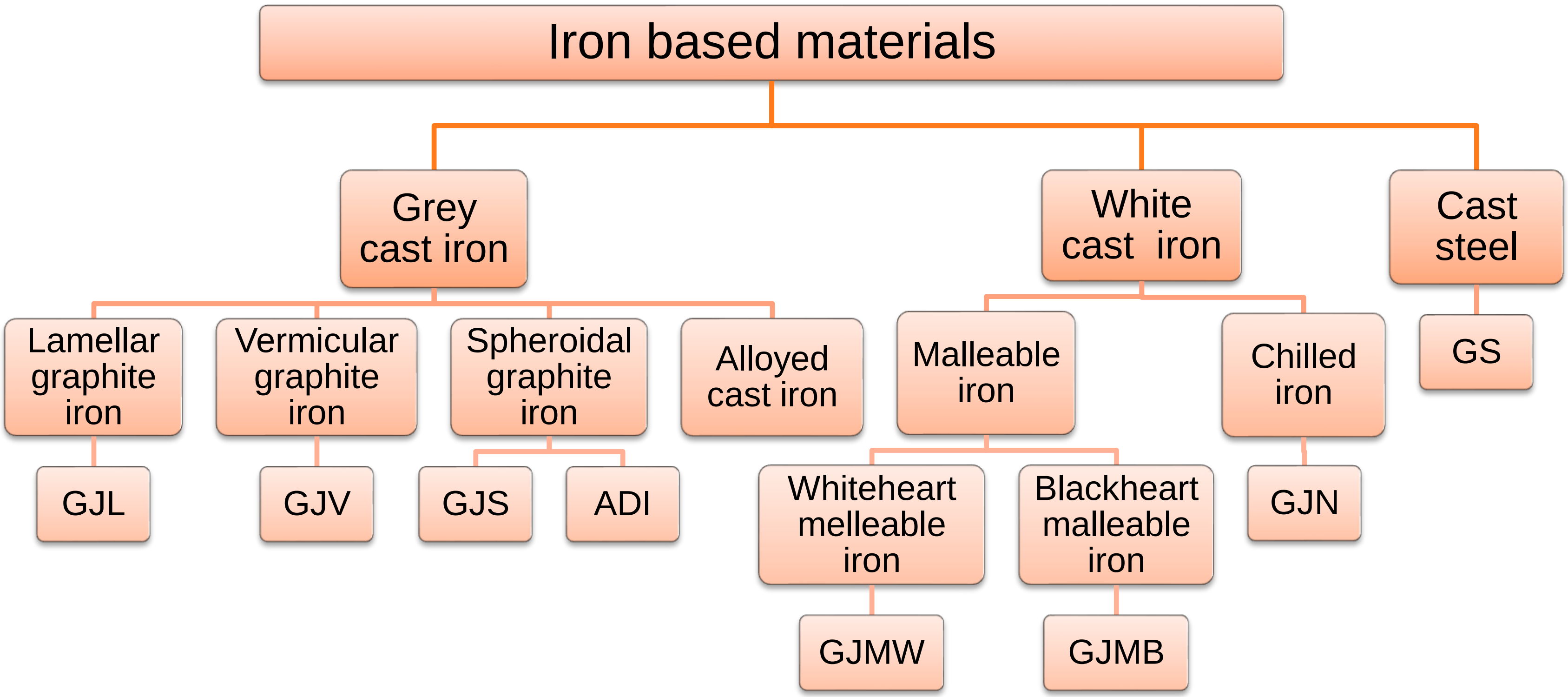
- Iron based
  - Grey iron
  - Nodular iron
  - White iron
  - Cast steel
- Nonferrous cast materials
  - Aluminium alloy
  - Magnesium alloy
  - Titanium alloy
  - Copper alloy
  - Nickel-base alloy

Iron-carbon diagram

- Cast iron
  - C > 2,06 %
- Grey cast iron
  - Stable system
  - Fe-C
  - Iron-graphite
  - Si, Ti, Al
- White cast iron
  - Metastable system
  - $Fe\text{-}Fe_3C$
  - Iron-cementite
  - Mn, Cr, Mo



Classification of iron based materials



Cast vs forged materials

The advantages of casting include:

- No real upper size limit in casting weight
- Large range of alloy choices
- As forgings remain solid, custom alloys are far more difficult to get into production whereas with casting, alloys including Chrome, Nickel and Moly can be added at the molten stage.
- Tooling is often less expensive than forge dies
- Smaller production series is possible
- Complicated/complex parts are no problem

Cast vs forged materials

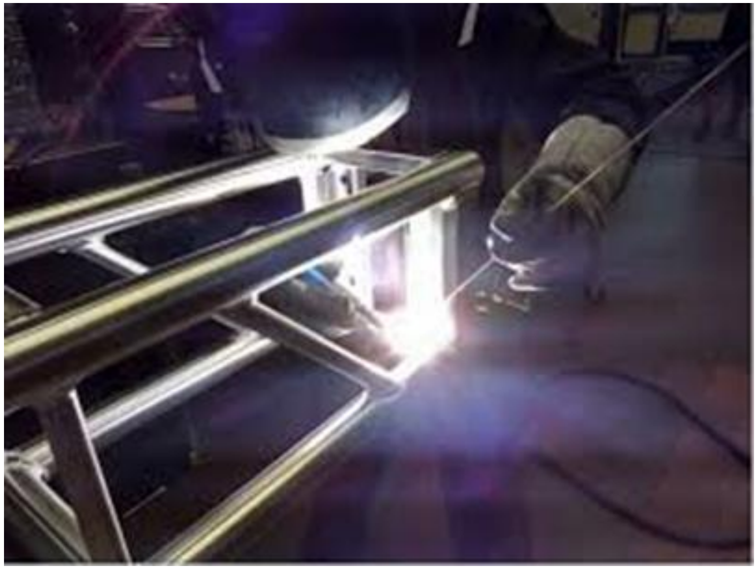
The advantages of forging include:

- Generally tougher than alternatives
- Will handle impact better than castings
- The nature of forging excludes the occurence of porosity, shrinkage, cavities and cold pour issues.
- The tight grain structure of forgings making it mechanically strong. There is less need for expensive alloys to attain high strength components.
- The tight grain structure offers great wear resistance without the need to make products “superhard”

Cast vs welded materials

The advantages of casting include:

- Welding during the fabrication process creates more stress and distortion due to localized heat. Casting, on the other hand, creates a more homogeneous microstructure as there is no heat affected zone.
- The ability to transition material thicknesses reduce stress.
- It’s possible to cast complex dimensions, shapes and sizes
- Converting a steel fabrication to a ductile iron casting also offers better machinability and greater vibration dampening properties

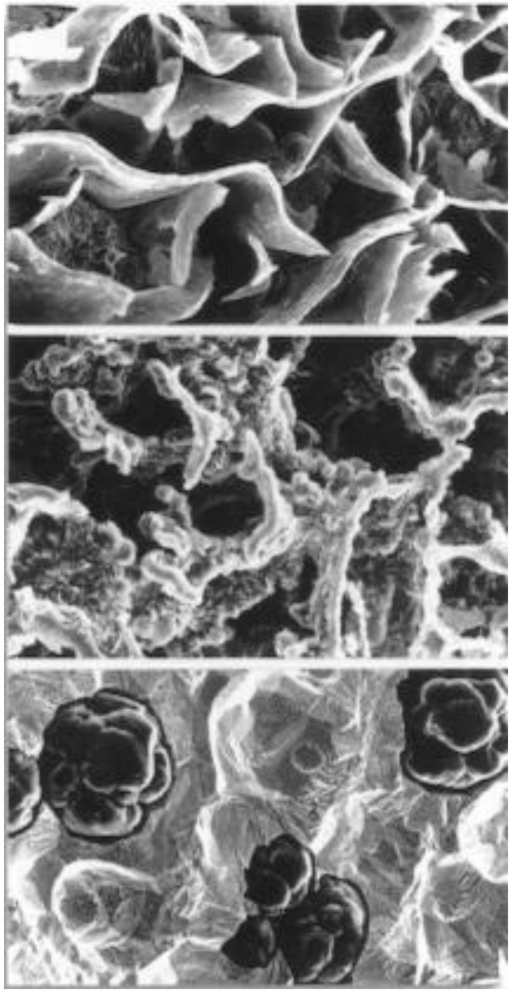


Cast iron

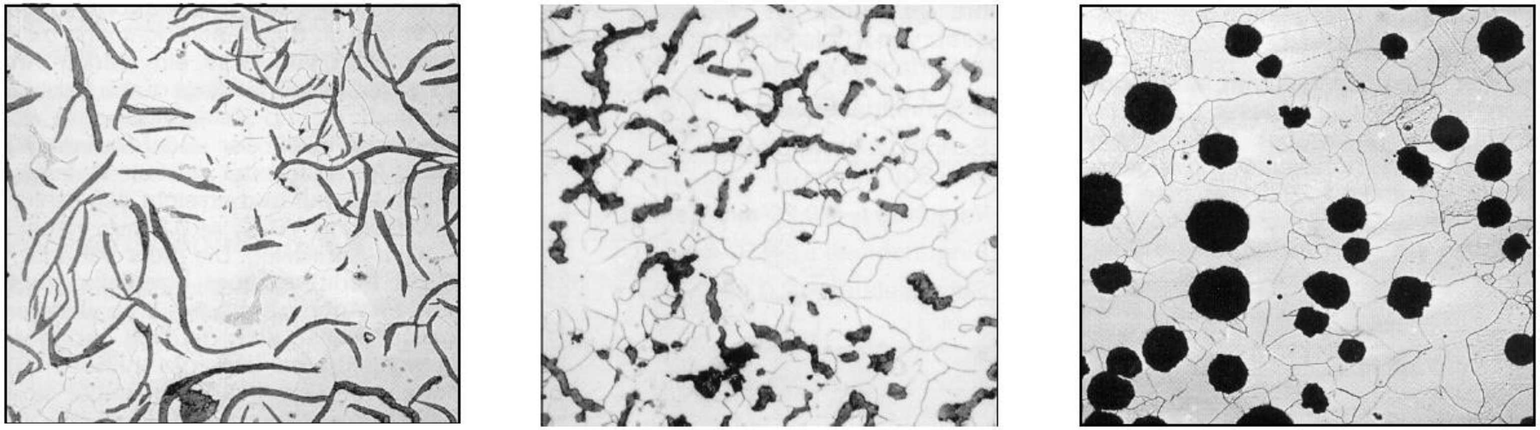
- Carbon cut out as Graphite
  - Grey color at the fracture surface
- Silicon
  - Graphite stabilizing
- Compressive strength higher than tensile strength (~2:1)
  - No bond between Iron and Carbon
- Good machinability
  - Carbon interrupts the metal micro-structure
  - Carbon lubricates the cutting tools
- Designation system: GJ(Symbol) - R_m

Cast iron - Overview

- **L**amellar graphite iron (GJ**L**)
  - Pressure and wear-resistant
  - Corrosion-resistant
  - Good damping characteristics
  - Low tensile strength and elongation at fracture
  - Low costs
- **V**ermicular graphite iron (GJ**V**)
  - Between GJL and GJS
  - Low thermal expansion
- **S**pheroidal graphite iron (GJ**S**)
  - Ductile
  - High tensile strength and elongation at fracture

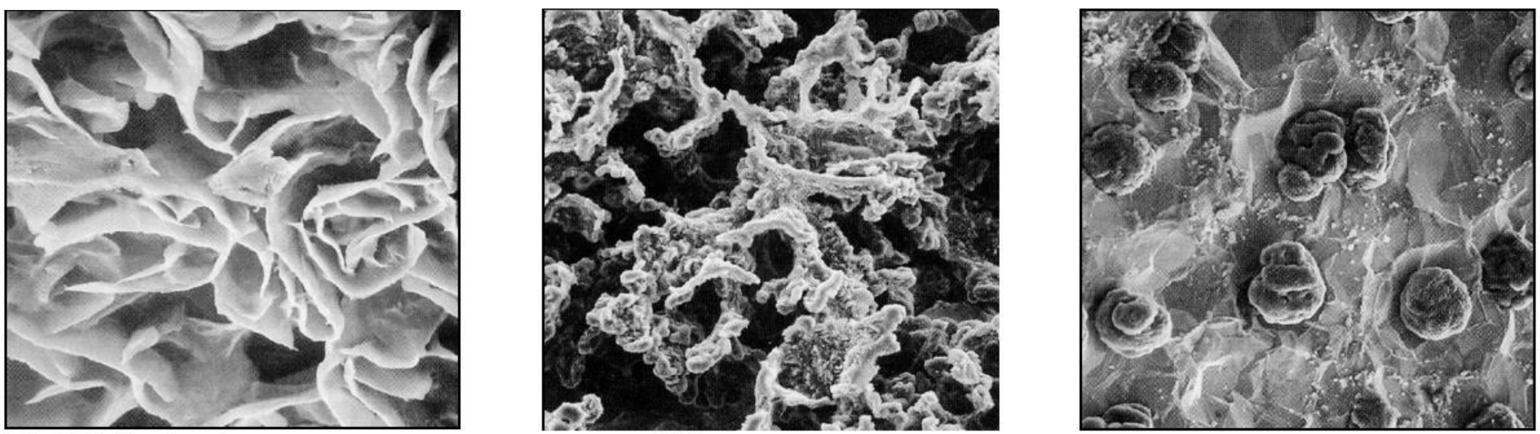


Cast iron - Overview



Un-etched photomicrograph

100 µm

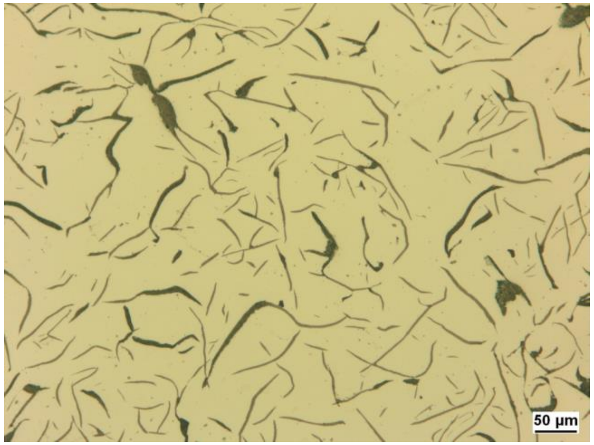


SEM image

20 µm

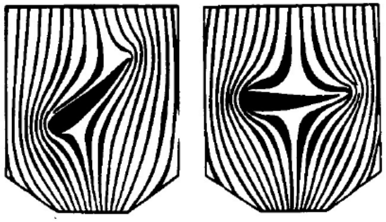
Quelle: CLAAS GUSS

Lamellar graphite iron GJL



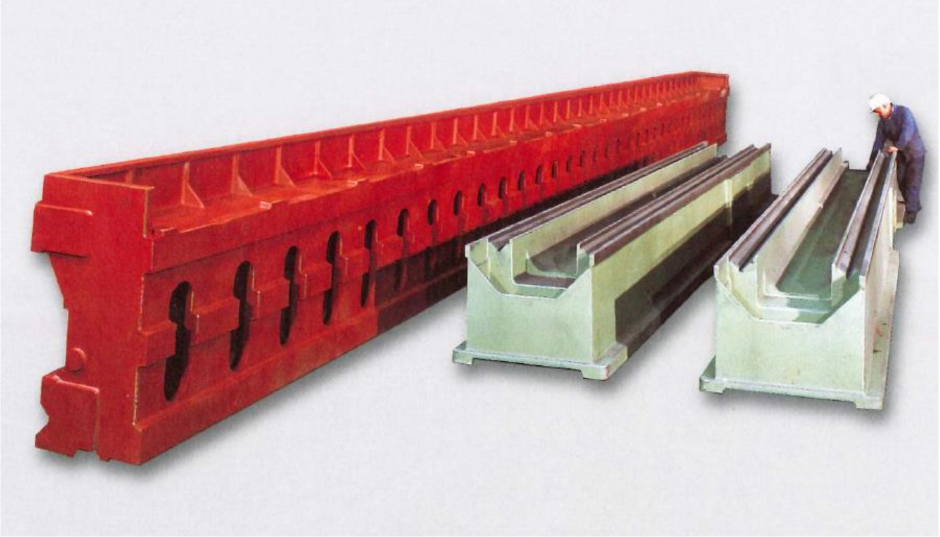
EN GJL-250

- Ferritic-pearlitic structure
  - $R_m \leq 400$ MPa
  - Poor toughness
  - Good compressive strength
- Cooling conditions affects microstructure
  - Tensile strength depends on wall-thickness
  - Higher strength in thin walls
- Very good damping capacity (Vibration)
  - GJL : GJS : Steel 1 : 1,8 : 4,3
- Notch-sensitive
  - High tension gradient at graphite flakes
- Good friction properties
- Very good pouring properties



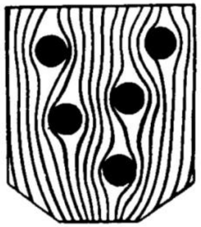
Lamellar graphite iron GJL

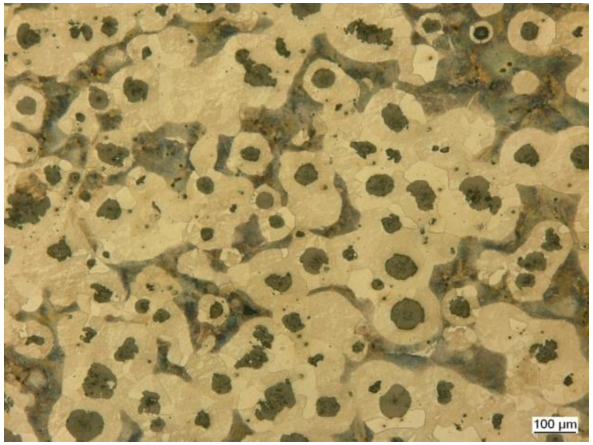
- Bed for machine tools
  - EN GJL-250 /-300
  - Up to 12,8 m
- Gearbox for a printing machine
  - EN GJL-250



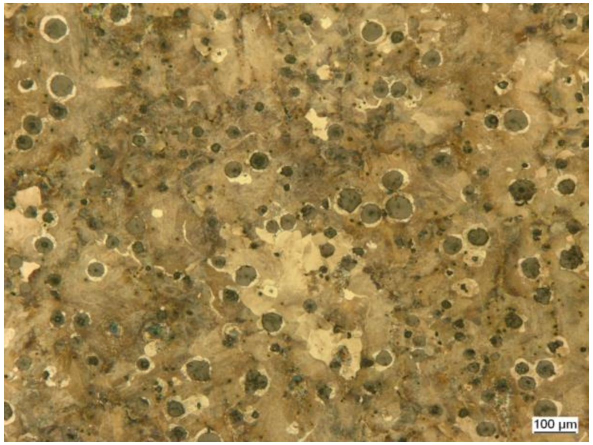
Spheroidal graphite iron GJS

- Add magnesium or cerium
  - Spheriodal graphite
- Ferritic-pearlitic structure
  - $R_m \leq 800$ MPa
  - Moderate toughness
- Less Notch-sensitive than GJL
  - Average tension gradient at graphite spheres
- Moderate damping capacity
- For mechanical stresses parts





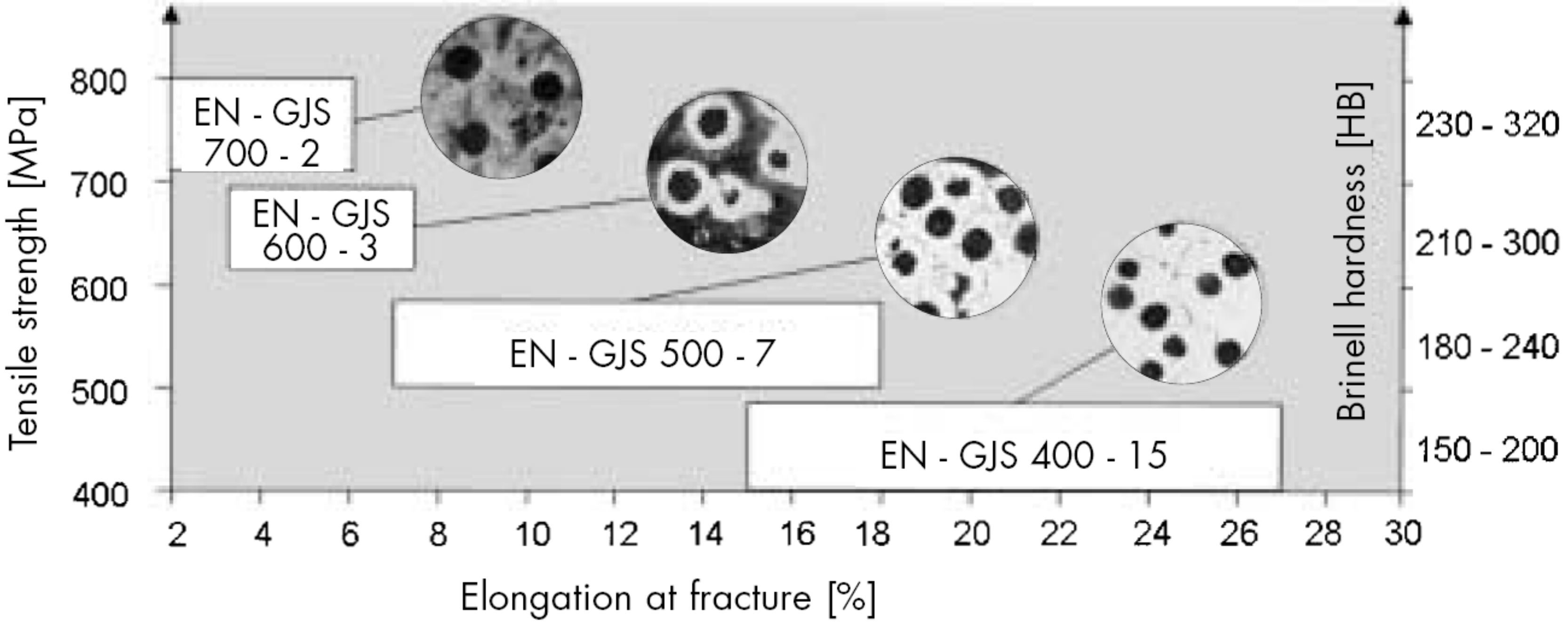
EN GJS-400



EN GJS-700

Spheroidal graphite iron GJS

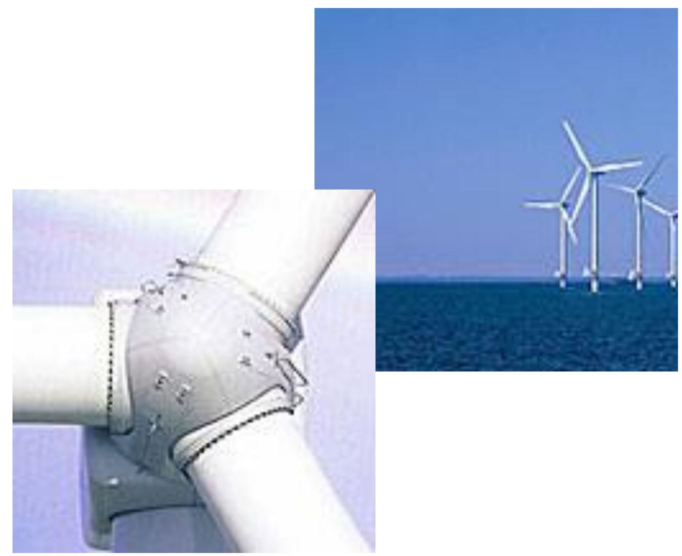
- High C- and Si-level
  - Low strength and Brinell hardness
  - High elongation at fracture



Spheroidal graphite iron GJS

- Cylinder block for marine diesel engine
  - EN GJS-400-18U
  - 9 x 2.84 x 3.35 m
  - 81‘450 kg

- Rotor hub (1.5MW)
  - EN GJS-400-18U-LT
  - 3.128 x 2.7 x 2.1 m
  - 8’400 kg



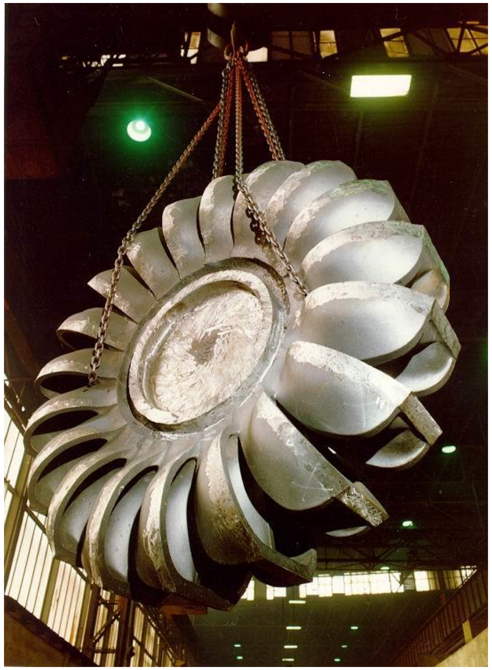
Cast steel GS

- Advantages
  - Mechanical properties of steel together with the castability
  - Malleable
  - Wide range of materials
  - Adjusable strengt properties
    - Heat treatment necessary
  - Welding!
  - Corrosion resistance!

- Disadvantages
  - Higher melting point > 1400°C
    - High demands on technology
  - Bad mould-filling capacity
    - More viscouse than cast iron
      - hypoeutectic
  - High shrinkage ~2%
  - Castings without heat treatment unusable
    - Brittle
    - Coarse grain
    - Dendritic

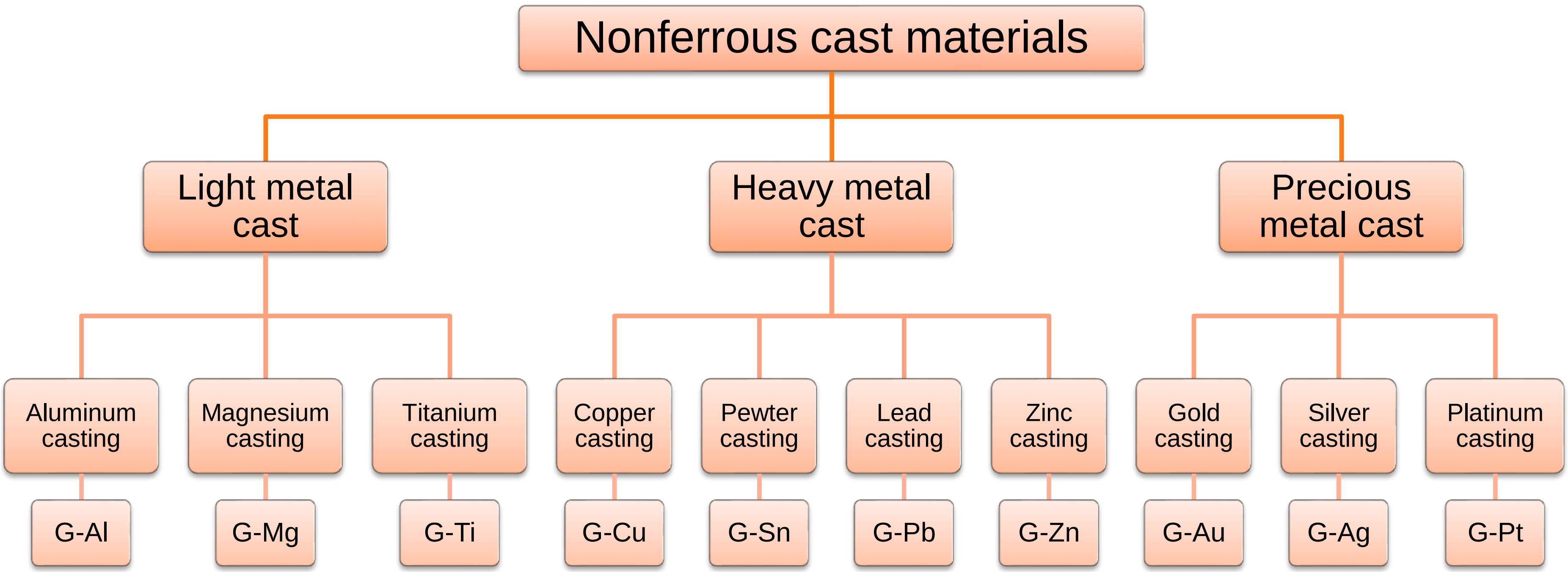
Cast steel GS

- Pelton wheel
  - High strengt



- Shunting switch
  - G-X120Mn12

Classification of nonferrous cast materials

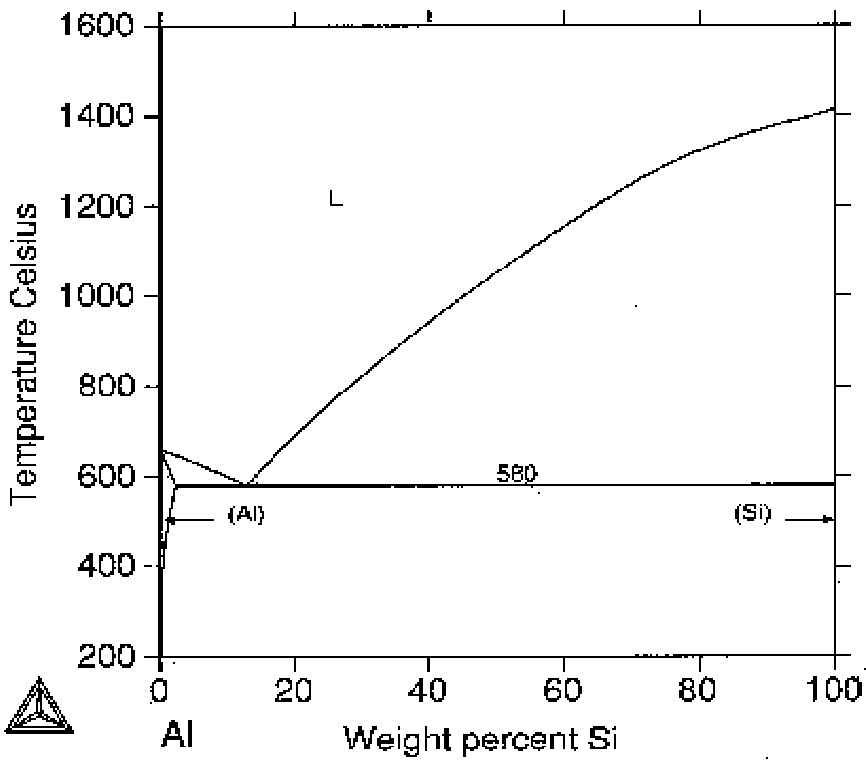


Aluminum alloy

- Suitable for complex thin-walled parts
- High dimensional accuracy
- Low weight with high rigidity
  - Good strength-weight ratio
- Smooth surfaces and edges
- Good machinability
- High thermal conductivity
- Good electrical conductivity
- Corrosion and weathering resistance
- Several surface treatments possible

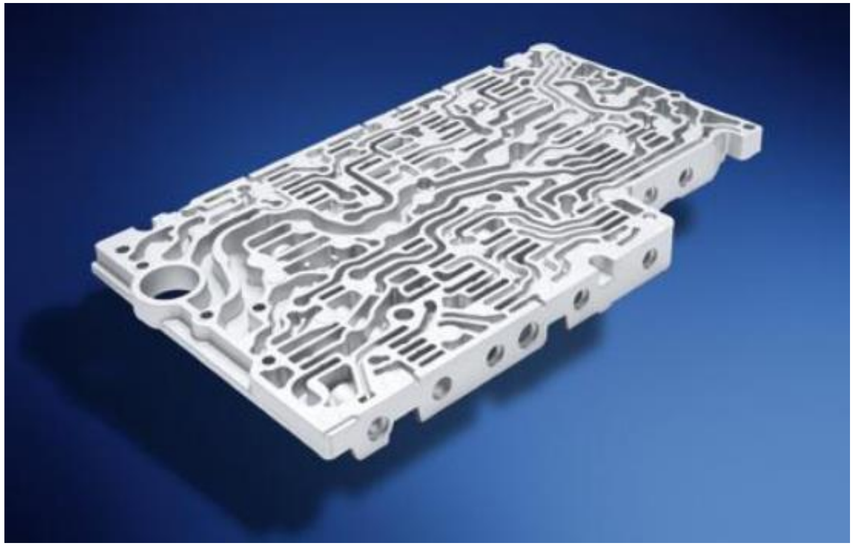
Aluminum alloy

- Al Si (4xxx)
  - Near eutectic (12% Si)
    - Low melting point (576°C)
    - Good fluidity
    - Less shrinkage
    - High strength
  - Hypereutectoid (up to 25% Si)
    - Used as piston alloy
    - Worse fluidity
    - Primary solidification of Si
    - Higher wear resistance due to Si crystals
    - Lower coefficient of expansion



Aluminum alloy

- Daimler valve body
  - AlSi9Cu3
  - Wall-thickness: 2-6mm
  - Drafts: 1° (valve core 5°)
- BMW integral cross member
  - EN AC - AlMg5Si2Mn
  - Weldable without pre-treatment



Magnesium alloy

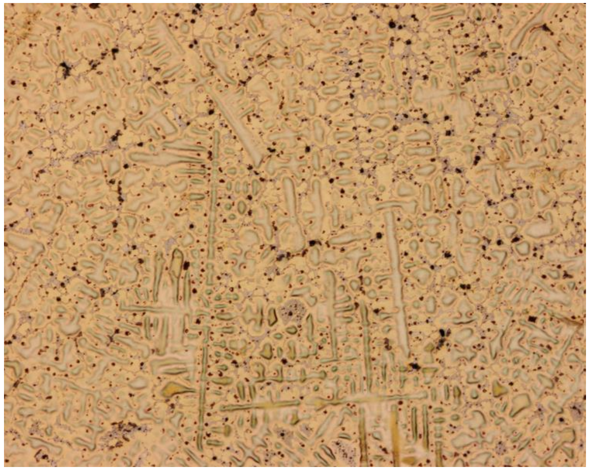
- Lightest of all structural metals
  - ~ 1800 kg/m^3
  - Excellent strength-weight ratio
- Hexagonal lattice
  - High strength
  - High electrical and thermal conductivity
  - Without Al and Zn
    - Brittle
    - Notch-sensitive
- Excellent machinability
- Good damping coefficient
  - Better vibration reduction than Al or GJx

Titanium alloy

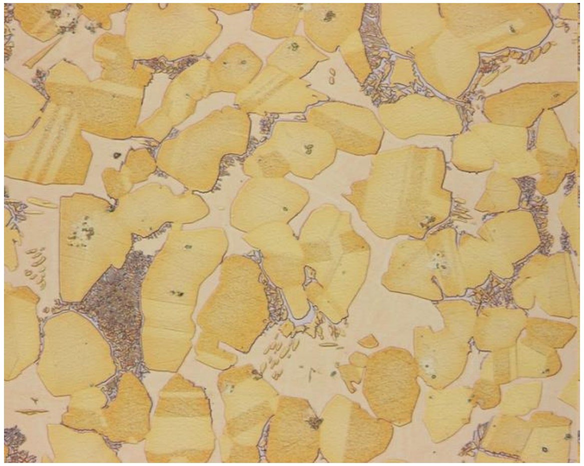
- Very high tensile strength and toughness
  - even at extreme temperatures
- Light weight
- Properties depending on phase
  - α phase
  - α+β phase
  - β phase
- Extreme corrosion resistance
  - Very dense TiO_2 layer
  - Biocompatibility
- Expensive

Copper alloy

- Properties
  - Corrosion resistance
  - Good bearing qualities
  - Attractive appearance
- Bronze
  - CuSn
- Brass
  - CuZn
- Red brass (gunmetal)
  - CuZnSn
- Aluminium bronze
  - CuAl



CuSn11 (50:1)



CuAl20 (500:1)

Bronze (CuSn)

- Up to 20% Sn
  - 9 – 12% for casting alloys
- Nonmagnetic
- High thermal and electrical conductivity
- High corrosion resistance
  - Seawater resistance
- Good wear resistance
- Good damping coefficient
- Red brass (CuZnSn)
  - Cheaper due to cheap Zn
  - Similar properties

Brass (CuZn)

- 5 to 45 % Zn
- Tensile strength up to 750 MPa
- No cryogenic embrittlement
- Good corrosion resistance
  - Depends on alloying element
- Antimicrobial
  - Used at public places
- Specialbrass
  - CuZn + other element

- Impeller for a pump
  - CuZn37Mn3Al2PbSi

- Multi Cone Synchro System
  - Depends on the application

Aluminium bronze (CuAl)

- 9 – 14% Al
- High corrosion resistance
  - Seawater resistance
- Good wear resistance
- Good cavitation resistance
- Applications
  - Ship propeller
  - Sliding elements
  - Bearings
  - Chemical industries
  - Gear wheels

- World largest ship propeller (MMG)
  - CuAl9Ni6Fe5Ma
  - Container ship with 120,000 PS
  - 9,6 m; 131 t