

Cast irons

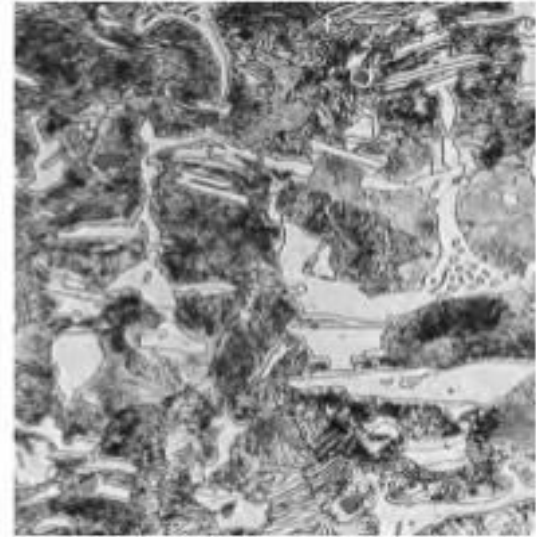
- ❑ Cast irons that were slowly cooled to room temperature consists of cementite, look whitish – *white cast iron*.
 - ❑ If it contains graphite, look grayish – *gray cast iron*.
 - ❑ It is heat treated to have graphite in form of nodules – *malleable cast iron*.
 - ❑ If inoculants are used in liquid state to have graphite nodules – *spheroidal graphite (SG) cast iron*.
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Cast Irons

- *The microstructure of cast iron has two extremes*
 1. *Liquid* —————→ *austenite + Fe₃C (white cast iron)*
 2. *Liquid* —————→ *austenite + graphite (gray, ductile...)*
- *graphite formation is promoted by*
 - *Slow cooling*
 - *High C and Si content*
 - *Heavy or thick section size*
 - *Inoculation particles*
 - *Presence of S, P, Al, Ni, Sn, Mn, Cu, Cobalt, antimony*
- **Formation of cementite (Fe₃C) is favored by**
 - **Fast cooling**
 - **Low C and Si contents**
 - **Thin sections**
 - **Alloying elements, titanium, vanadium, zirconium, chromium, manganese, and molybdenum**

White cast iron

- ❖ Carbon present in combined form (cementite) and there is no free carbon (graphite)
- ❖ Composition: C: 2.3-3%, Si: 0.5-1.3%, S: 0.06-0.1%, P: 0.1-0.2%, Mn: 0.5-1%
- ❖ Named after its white fractured surface
- ❖ No graphitisation and hence its solidification can be represented on I-C diagram
- ❖ **Properties:** Strong in compression (1750MPa), hard (350-500 BHN), resistant to abrasive wear, brittle, difficult to machine hence finishing to final size is done by grinding only
- ❖ Used to malleable CI
- ❖ **Applications:** Pump liners, Road roller surfaces, mill liners, grinding balls, dies and extrusion nozzles



Microstructures of white CI: the light cementite regions are surrounded by pearlite, which has the ferrite cementite layered structure. 200x [Source: William Callister, 2007]

1. WHITE CAST IRON

APPLICATION:

It can be used as liners of cement mixers, ball mills, drawing dies and extrusion nozzles.



NOZZLE



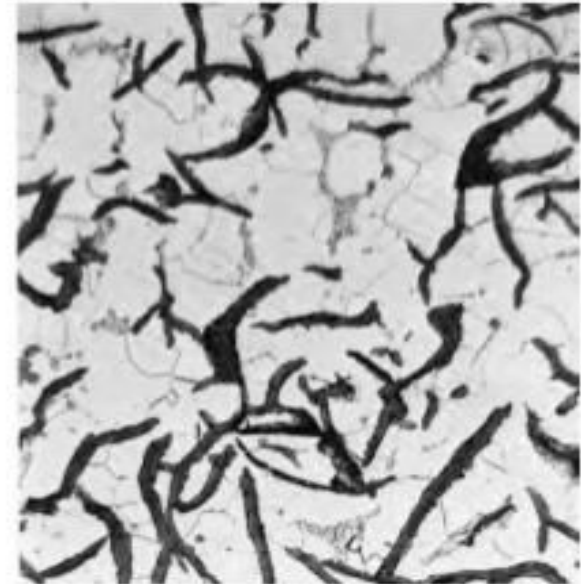
BALL MILLS



CEMENT MIXERS

Grey cast iron

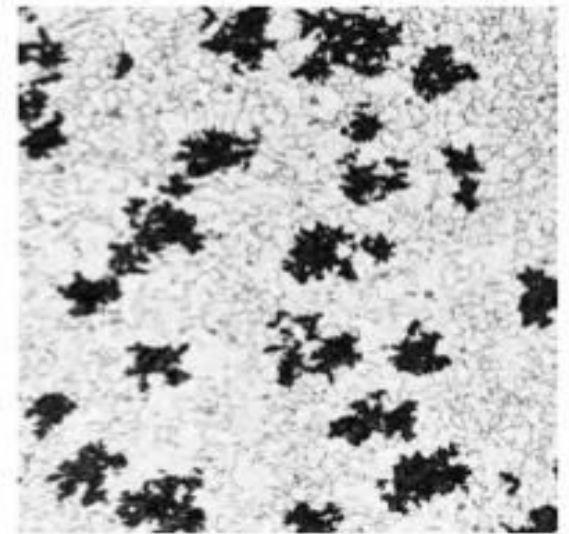
- ❖ Show gray fracture and contain graphite flakes
- ❖ Flakes are curved plates, interconnected in three dimensions
- ❖ Graphite formed during freezing
- ❖ Graphite flakes are sharp at their tips and act like internal cracks or stresses
- ❖ **Composition:** 2.5-3.8% C, 1.1-2.8% Si, 0.4-1% Mn, 0.15%P and 0.1% S
- ❖ **Properties: Depend upon morphology and size of graphite flakes**
- Brittle, weak in tension, strong in compression (as cracks do not propagate under compressive load)
- High fluidity and hence it can be cast into complex shapes and thin sections easily
- Low shrinkage during solidification
- Good wear resistance because graphite acts as lubricant
- Better damping capacity than steel
- Low notch sensitivity due to the presence of large number of internal sharp notches (edges of graphite flakes) which make the influence of external notch ineffective
- Easy to machine, as chip formation is promoted by graphite flakes. Also flakes serve as lubricant for cutting tool
- Good bearing properties
- Fairly good corrosion resistance



*Microstructures of Gray iron:
the dark graphite flakes are
embedded in an α -ferrite
matrix. 500x [Source: William
Callister, 2007]*

Malleable cast iron

- ❖ Heating white cast iron around 900° C and holding for long time (24hrs to several days), followed by very slow cooling to room temperature produces malleable cast iron
- ❖ Contains 2.5% C and 1% Si
- ❖ Cementite decomposes during the heat treatment to more stable form (graphite)
- ❖ The free carbon precipitates in the form of spheroidal particles (temper carbon)
- ❖ **Properties:**
 - Show ductility, toughness and are bendable
 - Good capacity to absorb shock and vibrations
 - NOT MALLEABLE; cannot be rolled, forged or extruded
 - T. S. = 700MPa, % elongation = 10-15%, Hardness = 80-275 BHN
- ❖ More expensive than grey cast iron because of heat treatment involved
- ❖ **Applications:** Automobile crankshaft, chain links and brackets, brake pedals, tractor springs, universal joint yoke



Microstructure of malleable CI: dark graphite rosettes (temper carbon) in an α -ferrite matrix. 150x [Source: William Callister, 2007]

Grey cast iron

- Low ductility and impact strength
- T. S. = 150-400MPa, Hardness = 150-300BHN, % elongation = < 1%
- ❖ Cheaper than steel (low temperatures involved in casting and low control on impurities as compared to steel)
- ❖ **Defects:**
 - Growth
 - Firecracks or heat checks
 - These defects can be reduced by adding Cr, Mo and Ni
- ❖ **Applications:** Manhole covers, M/c tool structures like bed, frames; Cylinder block and head of IC engine, Gas or water pipes for underground purpose, flywheels etc, elevators etc



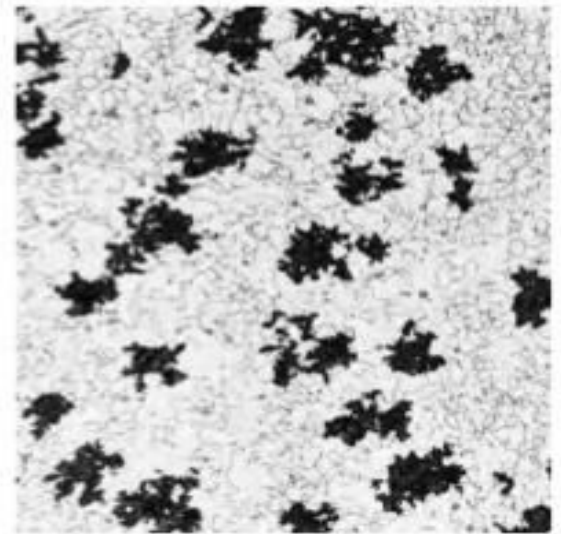
Manhole covers



Engine cylinder block

Malleable cast iron

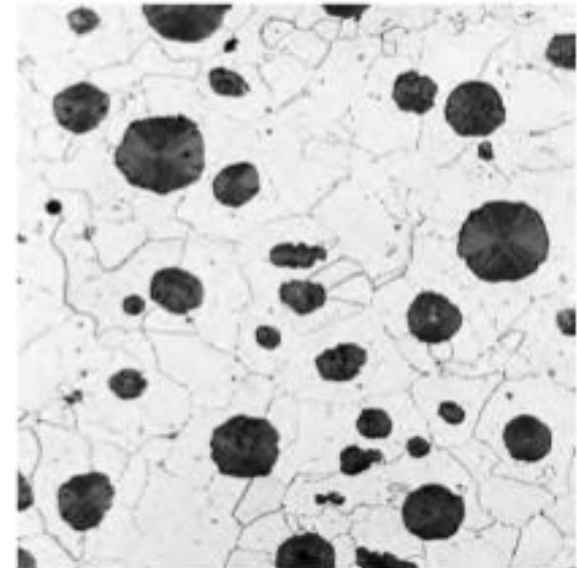
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Microstructure of malleable CI: dark graphite rosettes (temper carbon) in an α -ferrite matrix. 150x [Source: William Callister, 2007]

Nodular (Ductile or Spheroidal) cast iron

- ❖ Contains graphite in the form of spheroids
- ❖ Produced from grey cast iron by adding nodulising elements like Mg, Ca, Ba, Li, Zr or Ce
- ❖ **Composition:** 3.2-4.2% C, 1.1-3.5% Si, 0.3-0.8% Mn, 0.08% P, 0.2% S
- ❖ Since nodulising elements have strong affinity for sulphur and they scavenge sulphur from the molten bath as an initial step in producing nodular graphite. These elements are expensive and hence for effective utilization of these elements, the original grey melt must contain less amount of sulphur (< 0.03%). Sulphur content is reduced by treating the melt with soda ash
- ❖ **Properties:**
 - More tensile strength, ductility and toughness as compared to grey cast iron
 - Excellent machinability, castability and wear resistance
 - Do not suffer from defects like growth and firecracks
 - T. S. = 400-800MPa, % elongation = 10-18, Hardness = 100-300 BHN
- ❖ **Defects:**
 - Blow holes
 - Shrinkage
- ❖ **Applications:** Agricultural implements, industrial fan hub, Crankshafts, gears, punch dies, sheet metal dies, steel mill rolls and milling equipment, valves, pistons etc



Microstructure of nodular CI: the dark graphite nodules are surrounded by an -ferrite matrix. 200x [Source: William Callister, 2007]