Cast Iron

Cast Iron is still important today;

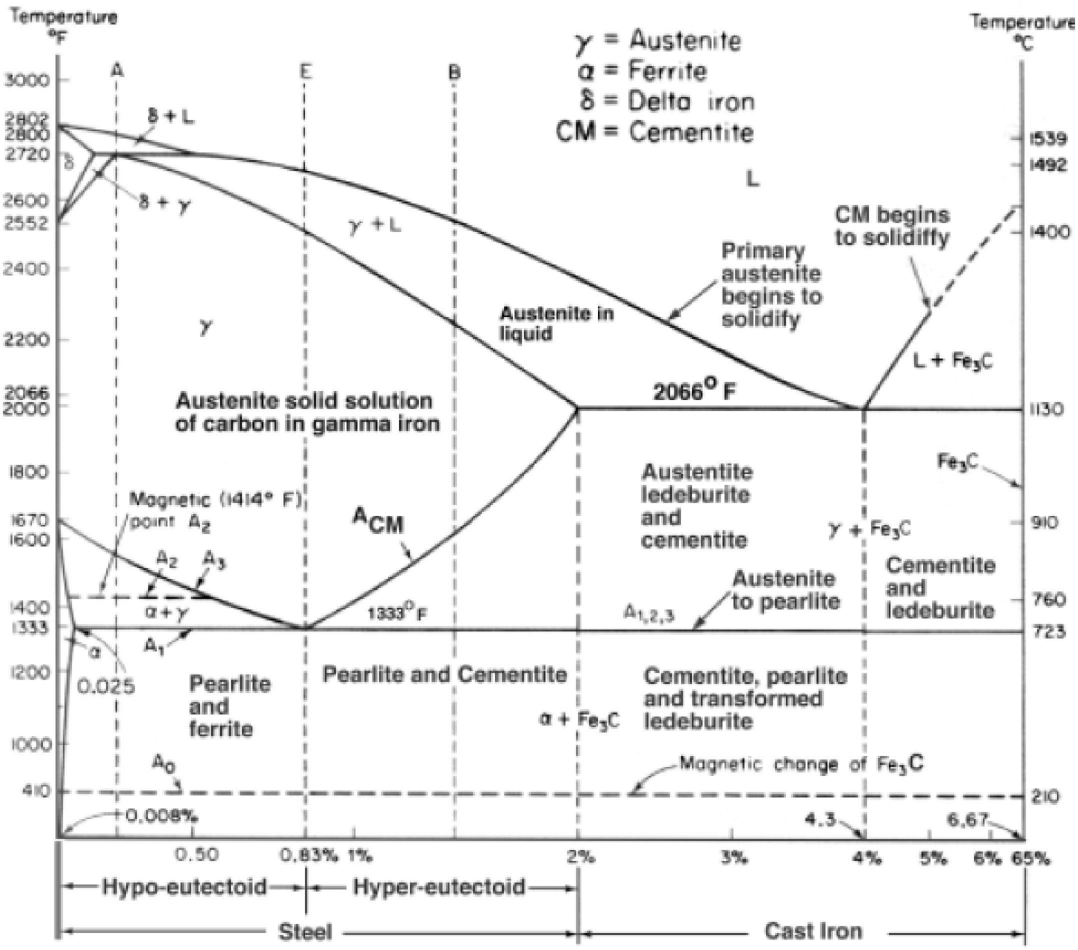
• It is cheap because it is close to the composition of ordinary pig iron.

• Mechanical rigidity and strength under compression are good.

• It machines with ease when a suitable composition is selected.

• Easy to cast because very fluid

• High-duty cast irons: e.g. spheroidal-graphite irons are strong, whilst malleable irons are tough.



Cast Iron in the Iron-Carbon equilibrium diagram

Cast Iron

• Ferrous alloys with > 2.1 wt% C

– More commonly 3 - 4.5 wt%C

• Low melting (also brittle) so easiest to cast

• Cementite decomposes to ferrite + graphite

$$Fe_3C \rightarrow 3\ Fe\ (\alpha) + C\ (graphite)$$

– Cementite (Fe_3C) a metastable phase

– Graphite formation promoted by

• Si > 1 wt%

• slow cooling

<u>Types of Cast Iron</u>

1. Gray iron

2. Nodular (ductile) iron

3. White iron

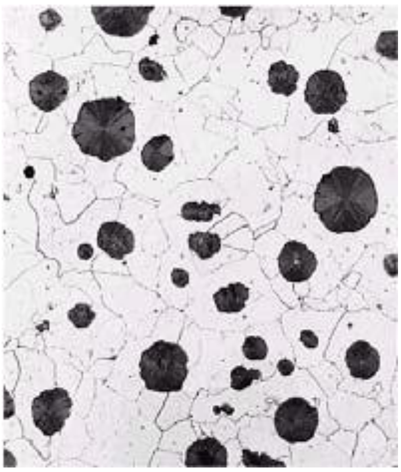
4. Malleable iron

5. Compacted graphite iron (CGI)

1. <u>Gray iron</u>

– 1 - 3 % Si, 2.5 – 4% C
– Graphite flakes plus ferrite/pearlite
– Brittleness due to the flake-like graphite
• Weak & brittle under tension
• Stronger under compression
• Excellent vibrational dampening
• Wear resistant

2. ***Ductile (nodular) iron***



– a small amount (0.05 wt%) of Mg or Ce

– Spheroidal graphite precipitates (nodules)

Rather than flakes

– Matrix often pearlite or ferrite

– Ductility increased by a factor of 20, strength is doubled

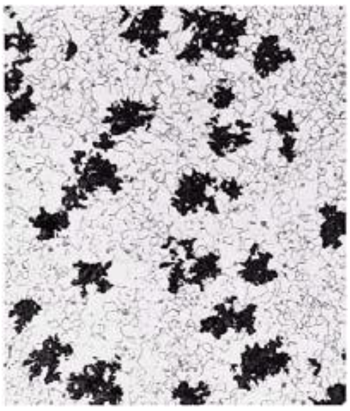
3. ***White iron***

– <1wt% Si, harder but brittle

– eutectic carbide plus pearlite

– large amount of Fe3C formed during casting

4. ***Malleable iron***



– the result of annealing white iron castings, 800º-900º C

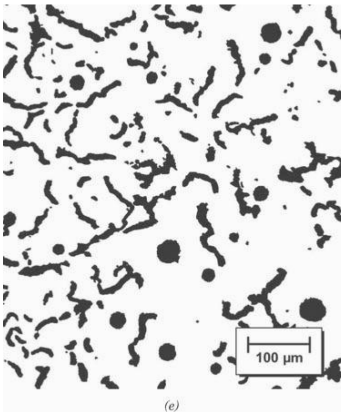
– cementite→ graphite precipitates, clusters or rosettes

– more ductile

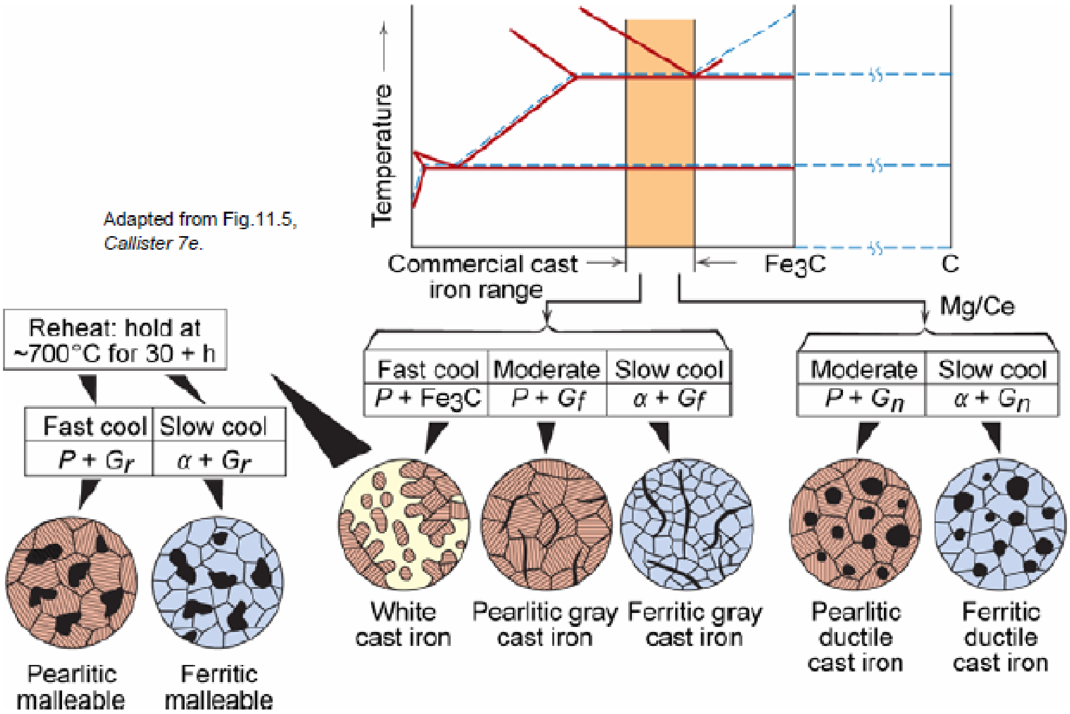
5. Compacted graphite iron (CGI)

1. C: 3.1-4.0%, Si: 1.7-3.0%
2. Lower content of Mg or Ce
3. Worm-like (vermicular) graphite particles

- higher thermal conductivity
- better resistance to thermal shock
- lower oxidation at elevated temperature



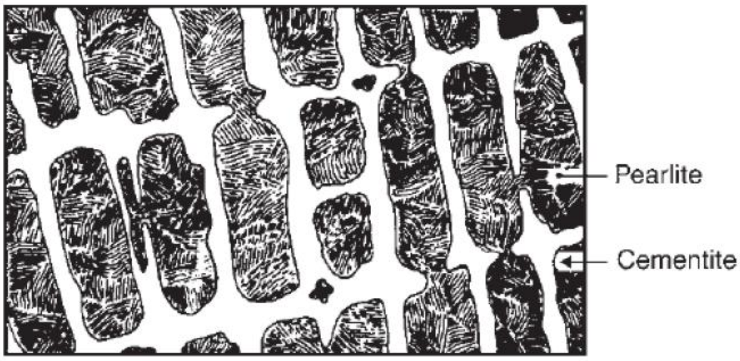
Production of Cast Iron



Composition of cast irons

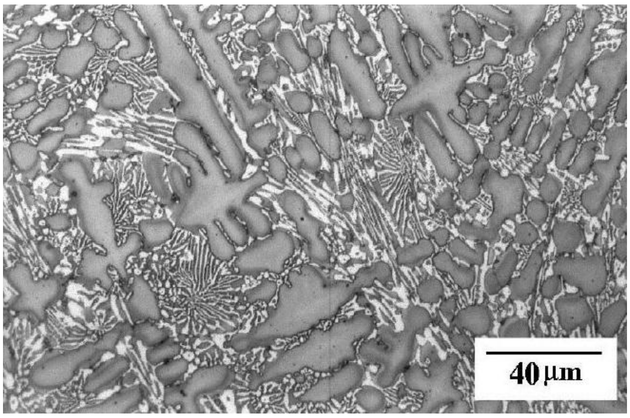
Ordinary cast irons contain the following elements,

- **Carbon** 3.0-4.0%, (as graphite: grey CI, or iron carbide: white CI)
- **Silicon** 1.0-3.0%, (breaks down Fe3C, prefers grey CI)
- **Sulphur** up to 0.1%, (encourages Fe3C, but embrittlement)
- **Manganese** 0.5-1.0%, (toughens by reversing Sulphur, modify ferrite)
- **Phosphorus** up to 1.0%, (Brittle: keep to minimum, raise fluidity)

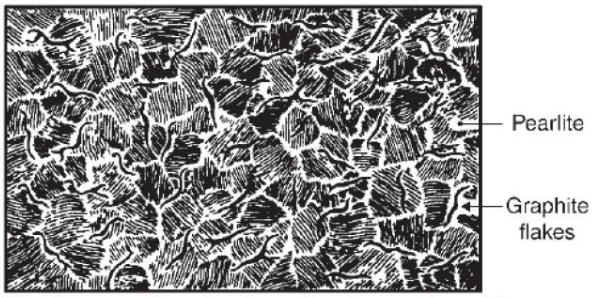


(i) **White cast iron** (low silicon) – primary cementite network in a matrix of pearlite.

The effects of silicon content on the structure of cast iron.



White cast iron



(ii) **Fine grey iron** (medium silicon) – small graphite flakes in a matrix of pearlite.

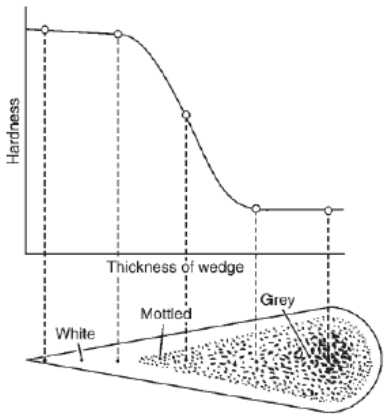
Fine grey iron

(iii) **Coarse grey iron** (high silicon) – large graphite flakes in a matrix of ferrite.

Coarse grey iron

The influence of cooling rate on the properties of a cast iron

Adding silicon makes cementite unstable, decomposing slowly.
If cooled rapidly cementite is trapped and forms white iron.
If cooled slowly the cementite can decompose into graphite, forming grey iron.
More slowly > coarser gray iron.



The effect of sectional thickness on the depth of chilling of grey iron

Alloying elements improve the mechanical properties of an iron, by:

- Refining the grain size.
- Stabilising hard carbides.
- Producing cast irons with a martensitic or austenitic structure.

1. ***Nickel:*** Graphitising effect on cementite (tends to grey iron). Refines grains for heavy sections – improving toughness.
2. ***Chromium:*** Forms chromium carbide (harder than cementite). Wear resistance. Less susceptible to cementite 'growth‘.
3. ***Molybdenum:*** Increases hardness and toughness of thick sections.
4. ***Vanadium:*** Increases strength and hardness. Better heat-resistance by stabilising carbides so that they do not decompose on heating.
5. ***Copper:*** Not much solubility but resists rusting.