ISSUES TO ADDRESS...

• How are metal alloys classified and what are their common applications?
• What are the microstructure and general characteristics of cast irons?
• What are the distinctive physical and mechanical properties of nonferrous alloys?
Classification of Metal Alloys

Metal Alloys

Ferrous

Steels

<1.4 wt% C

Cast Irons

3-4.5 wt% C

Nonferrous

Cast Irons

3-4.5 wt% C

Steels

<1.4 wt% C

microstructure: ferrite, graphite/cementite

Adapted from Fig. 13.1, Callister & Rethwisch 9e.


Fig. 11.23, Callister & Rethwisch 9e.
Based on data provided in Tables 13.1(b), 14.4(b), 13.3, and 13.4, Callister & Rethwisch 9e.
Refinement of Steel from Ore

Iron Ore $\rightarrow$ Coke

$3\text{CO} + \text{Fe}_2\text{O}_3 \rightarrow 2\text{Fe} + 3\text{CO}_2$

$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$

$\text{CO}_2 + \text{C} \rightarrow 2\text{CO}$

$3\text{CO} + \text{Fe}_2\text{O}_3 \rightarrow 2\text{Fe} + 3\text{CO}_2$

$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

$\text{CaO} + \text{SiO}_2 + \text{Al}_2\text{O}_3 \rightarrow \text{slag}$
Ferrous Alloys

Iron-based alloys

- Steels
- Cast Irons

Nomenclature for steels (AISI/SAE)

10xx Plain Carbon Steels
11xx Plain Carbon Steels (resulfurized for machinability)
15xx Mn (1.00 - 1.65%)
40xx Mo (0.20 ~ 0.30%)
43xx Ni (1.65 - 2.00%), Cr (0.40 - 0.90%), Mo (0.20 - 0.30%)
44xx Mo (0.5%)

where xx is wt% C x 100

example: 1060 steel – plain carbon steel with 0.60 wt% C

Stainless Steel >11% Cr
Cast Irons

- Ferrous alloys with > 2.1 wt% C
  - more commonly 3 - 4.5 wt% C
- Low melting – relatively easy to cast
- Generally brittle

Cementite decomposes to ferrite + graphite

\[ \text{Fe}_3\text{C} \rightarrow 3 \text{Fe} (\alpha) + \text{C} (\text{graphite}) \]

- generally a slow process
Graphite formation promoted by
• Si > 1 wt%  
• slow cooling

**Fig. 13.2, Callister & Rethwisch 9e.**
[Adapted from *Binary Alloy Phase Diagrams*, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]
Types of Cast Iron

Gray iron
- graphite flakes
- weak & brittle in tension
- stronger in compression
- excellent vibrational dampening
- wear resistant

Ductile iron
- add Mg and/or Ce
- graphite as nodules not flakes
- matrix often pearlite – stronger but less ductile

Figs. 13.3(a) & (b), Callister & Rethwisch 9e.
[Courtesy of C. H. Brady and L. C. Smith, National Bureau of Standards, Washington, DC (now the National Institute of Standards and Technology, Gaithersburg, MD)]
Types of Cast Iron (cont.)

White iron

- < 1 wt% Si
- pearlite + cementite
- very hard and brittle

Malleable iron

- heat treat white iron at 800-900°C
- graphite in rosettes
- reasonably strong and ductile

Figs. 13.3(c) & (d), Callister & Rethwisch 9e.
Types of Cast Iron (cont.)

Compacted graphite iron
- relatively high thermal conductivity
- good resistance to thermal shock
- lower oxidation at elevated temperatures
Production of Cast Irons


Reheat: hold at ~700°C for 30 + h

<table>
<thead>
<tr>
<th>Fast cool</th>
<th>Slow cool</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P + G_f$</td>
<td>$\alpha + G_f$</td>
</tr>
</tbody>
</table>

Pearlitic malleable
Ferritic malleable

Fast cool
- $P + Fe_3C$
- White cast iron
- Pearlitic cast iron
- Ferritic cast iron

Moderate
- $P + G_f$
- Pearlitic ductile cast iron

Slow cool
- $\alpha + G_f$
- Ferritic ductile cast iron
Limitations of Ferrous Alloys

1) Relatively high densities
2) Relatively low electrical conductivities
3) Generally poor corrosion resistance
Nonferrous Alloys

• **Cu Alloys**
  Brass: Zn is subst. impurity (costume jewelry, coins, corrosion resistant)
  Bronze: Sn, Al, Si, Ni are subst. impurities (bushings, landing gear)
  Cu-Be: precip. hardened for strength

• **Al Alloys**
  -low $\rho$: 2.7 g/cm$^3$
  -Cu, Mg, Si, Mn, Zn additions
  -solid sol. or precip. strengthened (struct. aircraft parts & packaging)

• **Mg Alloys**
  -very low $\rho$: 1.7 g/cm$^3$
  -ignites easily
  -aircraft, missiles

• **Ti Alloys**
  -relatively low $\rho$: 4.5 g/cm$^3$
  -vs 7.9 for steel
  -reactive at high $T$’s
  -space applic.

• **Noble metals**
  -Ag, Au, Pt
  -oxid./corr. resistant

• **Refractory metals**
  -high melting $T$’s
  -Nb, Mo, W, Ta

Based on discussion and data provided in Chapter 13, *Callister & Rethwisch 9e.*

AMSE 205 Spring ‘2016
Summary

- Ferrous alloys:
  -- steels
  -- cast irons
- Non-ferrous alloys:
  -- Cu, Al, Ti, and Mg alloys; refractory alloys; and noble metals