# Ferrous Alloys

- The properties of steels, determined by dispersion strengthening, depend on the amount, size, shape, and distribution of cementite ($Fe_3C$).

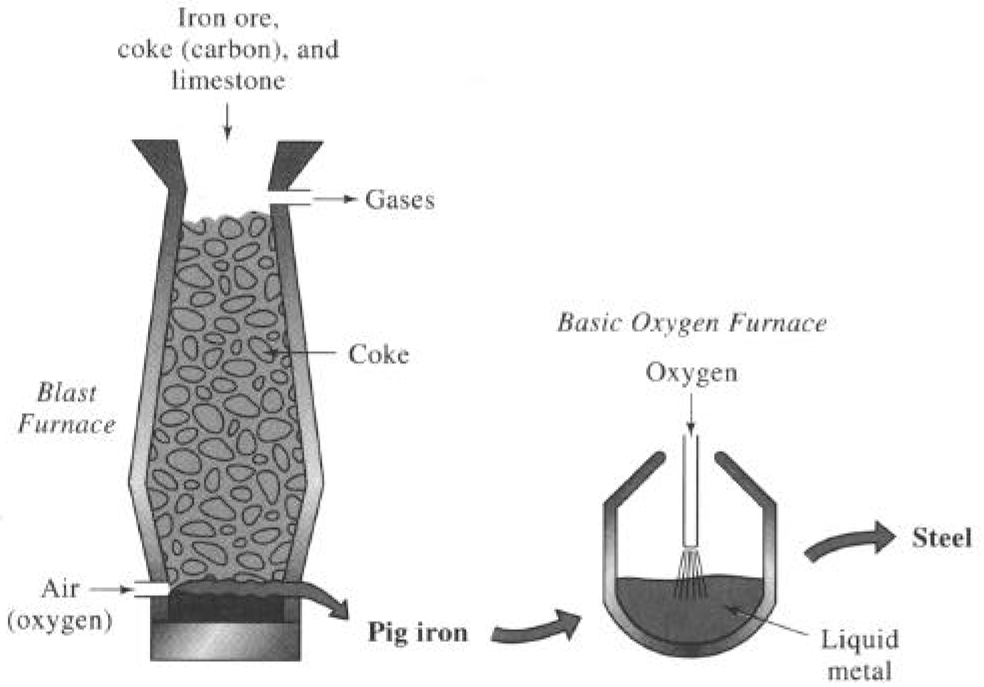
- These factors are controlled by alloying and heat treatment.

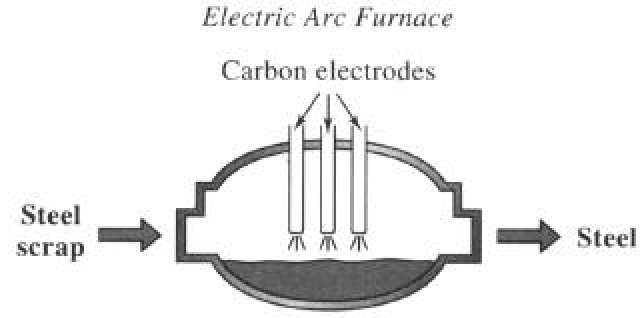
# Steel

Old Big Steel Mills

vs.

The New Mini-Mills



# AISI Designations

| AISI-SAE Number | % C | % Mn | % Si | % Ni | % Cr | Others |
|---|---|---|---|---|---|---|
| 1020 | 0.18–0.23 | 0.30–0.60 | | | | |
| 1040 | 0.37–0.44 | 0.60–0.90 | | | | |
| 1060 | 0.55–0.65 | 0.60–0.90 | | | | |
| 1080 | 0.75–0.88 | 0.60–0.90 | | | | |
| 1095 | 0.90–1.03 | 0.30–0.50 | | | | |
| 1140 | 0.37–0.44 | 0.70–1.00 | | | | 0.08–0.13% S |
| 4140 | 0.38–0.43 | 0.75–1.00 | 0.15–0.30 | | 0.80–1.10 | 0.15–0.25% Mo |
| 4340 | 0.38–0.43 | 0.60–0.80 | 0.15–0.30 | 1.65–2.00 | 0.70–0.90 | 0.20–0.30% Mo |
| 4620 | 0.17–0.22 | 0.45–0.65 | 0.15–0.30 | 1.65–2.00 | | 0.20–0.30% Mo |
| 52100 | 0.98–1.10 | 0.25–0.45 | 0.15–0.30 | | 1.30–1.60 | |
| 8620 | 0.18–0.23 | 0.70–0.90 | 0.15–0.30 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25% V |
| 9260 | 0.56–0.64 | 0.75–1.00 | 1.80–2.20 | | | |

# Surface Treatments

- **Surface Heat Treatment -** The surface is quickly heated, quenched, and then tempered
- **Carburizing -** diffusion of carbon into the surface to increase the carbon at the surface
- **Nitriding -** Similar to Carburizing but nitrogen (N) is substituted for carbon

# Stainless Steels

- Ferritic Stainless Steels (BCC)- Up to 30% Cr and less then 0.12% C. Good corrosion resistance
- Martensitic Stainless Steels - Cr < 17%. Heat treatable with the ability to form martensite among other phases
- Austenitic Stainless Steels (FCC)- Ni is an austenite stabilizing element.

# Cast Iron

- Grey Cast Iron - Interconnected graphite flakes in pearlite matrix. Good vibration damping.
- White Cast Iron - Used for their high hardness and wear resistance. Martensite can be formed.
- Malleable Cast Iron - A heat treated unalloyed 3% carbon white iron.
- Nodular Cast Iron - The addition of magnesium (Mg) causes spheroidal graphite to grow.

# Nonferrous Alloys

- Non Iron based alloys
- Wide range of properties, structures, and strengthening mechanisms.
- $$ Cost. $$
- Selecting the right material to fit the application.

# Specific Strength

| Metal | Density (lb/in.$^3$) | Tensile Strength (psi) | Cost per lb ($) |
|---|---|---|---|
| Aluminum | (0.097) | 83,000 | 0.60 |
| Beryllium | (0.067) | 55,000 | 300.00 |
| Copper | (0.322) | 150,000 | 1.10 |
| Lead | (0.410) | 10,000 | 0.35 |
| Magnesium | (0.063) | 55,000 | 1.40 |
| Nickel | (0.321) | 180,000 | 4.10 |
| Titanium | (0.163) | 160,000 | 5.50 |
| Tungsten | (0.695) | 150,000 | 10.00 |
| Zinc | (0.257) | 75,000 | 0.55 |
| Iron | (0.284) | 200,000 | 0.10 |

# Aluminum Alloys

- Second most plentiful metal on earth
- Hall-Heroult process - electrolytic reduction of $Al_2O_3$ to liquid metal
- One-third the density of Steel
- Aluminum alloys can be up to 30 times stronger then pure Aluminum
- Wrought & Casting Alloys
- Al - Li Alloys

# Magnesium Alloys

- Extracted electrolytically from concentrated magnesium chloride in seawater
- Density = 1.74g/$cm^3$  (lighter then Al)
- Specific strength comparable to Al
- Poor corrosion resistance in a marine environment

# Beryllium Alloys

- Modulus of Elasticity = 42 x $10^6$ psi (stiffer then steel)
- Density = 1.848 g/$cm^3$ (light then Al)
- Expensive $$$$$$, complicated production
- It can be toxic, BeO is a carcinogenic material for some people.

# Copper Alloys

- Heavier then Steel, lower specific strength then Aluminum
- Many copper alloys are excellent electrical conductors
- Brass - Copper-Zinc alloys w/ < 40% Zn
- Bronze - Copper-Tin alloys w/ < 10% Sn
- Copper-Beryllium alloys are non-sparking

# Nickel Alloys

- High temperature alloys.
- Great corrosion resistance
- Supperalloys - Nickel, iron-nickel, and cobalt. (high strength at high temperatures)
- Solid solution, dispersion strengthening and precipitation hardening

# Titanium Alloys

- The Kroll process - conversion of $TiO_2$ to $TiCl_4$ which is then reduced to titanium metal
- Higher specific strength then aluminum
- excellent corrosion resistance and high temperature properties
- Alpha ($\alpha$) and Beta ($\beta$) titanium alloys

# Refractory Metals

- Exceptionally high melting temperatures

- Tungsten (W) - 3,410$^{o}$C
- Molybdenum (Mo) - 2,610$^{o}$C
- Tantalum (Ta) - 2,996$^{o}$C
- Niobium or Columbium (Nb) - 2,468$^{o}$C