An Introduction to Steel and Steel Metallurgy
Metallurgy (and Materials Science) Summary

- Processing
- Structure
- Properties
- Performance
Outline

- What is steel?
- Mining for steel ingredients
- Steel Processing
  - Making
  - Shaping
  - Heat treating
- Structure
  - From atoms...
  - To crystals...
  - To microstructures.

Properties
- Strength
- Toughness
- Hardness
Steel
What is Steel?

- An alloy (mixture) of iron and carbon (<2.0%)
- Plain Carbon Steel contains Manganese (>0.25%)
- Alloy steels contain additional alloying elements, typically C, Mn, Si, Cr, Ni, Mo, Al and sometimes Ti, V, Nb, W, Co.
- Typically Steels have 95% or more Iron with relatively small alloy additions.
- Stainless and other special steels might have as little as 60-70% Iron.
- Steel is highly recyclable.
Minerals and Mining
The mineral Taconite is present as sedimentary rock in places like northern Minnesota and Michigan. Taconite contains about 25% Iron (Fe) in the form of Magnetite ($\text{Fe}_3\text{O}_4$) and Hematite($\text{Fe}_2\text{O}_3$).

After mining and processing the concentrated iron ore pellets contain about 66% Fe with some silica ($\text{SiO}_2$), Lime ($\text{CaO}$) a small amount of other metals, Phosphorus, and oxygen.
Actively producing mines around the world (not just iron mines)
Where do other minerals for steel making come from?

- Iron (Fe) – Northern USA, Canada, Australia...
- Carbon – All over
- Manganese (Mn) – Australia, Africa, China, Europe...
- Chrome (Cr) – Europe, Russia, Asia, USA...
- Nickel (Ni) – Canada, Europe, Asia...
- Molybdenum (Mo) – Canada, Africa, Russia, Asia...

Must be careful not to source minerals from Democratic Republic of Congo regions

“conflict minerals”
Processing

Steel Making and Shaping

Heat Treating
STEEL MAKING

Two ways to make steel

- Integrated Steel Mills
- Mini Mills
STEEL MAKING

Integrated Steel Making Flowline

- Iron Ore
- Pellets
- Sinter
- Crushed
- Limestone
- Coal
- Coke Ovens
- Blast Furnace
- Direct Reduction
- Scrap
- Lime & Flux
- Oxygen
- Molten Iron
- Basic Oxygen Furnace
- Slag
Your Guide to the Faircrest Steel Plant

- Faircrest has more than 350 operational associates, producing more than one million melt tons of steel per year.
- The soaking pits use as much natural gas as the annual consumption of 8,500 homes.
- In a year, Faircrest melts the equivalent of 1.2 million scrap cars.
- About 20 football fields could fit under the roof of the Faircrest Steel Plant.
- The concrete used in the construction of Faircrest could build a 31/4-foot-wide (1.1 meters) sidewalk from Canton to the White House.

*Data from 2011.

Manufacturing Process:
1. Scrap Loading
2. Melting
3. Refining
4. Teeming
5. Jumbo Vertical Bloom Caster
6. Mold Make-Up
7. Soaking Pits
8. Forge Press
9. 46-inch Blooming Mill
10. Scarfer
11. Bloom Shear
12. 36-inch Billet Mill
13. Billet Saws
14. Billet Identification and Cooling
15. Roll Shop
16. Billet Conditioning
Steel Manufacturing Process

Mini Mill Steel Making Flowline

- Scrap
- Melting
- Electric Arc Furnace
- Strand Casting
- Ladle
- Rolling Mill
STEEL MAKING

BOTTOM POURING - LADLE/INGOT MOLDS

- Ladle Cover
- Refractory Lining
- Treatment and Teeming Ladies
- Rotary Nozzles
- Argon Gas Shroud Around Stream
- Hot Top Side Boards
- Trumpet
- Mold Powder
- Ingot Mold
- Donut
- Runner Brick
- Trumpet Brick (Backed with Sand)
- Mold Stool
- Stool Plate
Solidification of Steel

Dendritic Zones

Equiaxed Zone
Soap Bubbles as an Analog for Grains
STEEL SHAPING

Piercing

Reheat → Pierce → Elongate → Reduce → Size → Gage → Mill Anneal → Hot Bed Cool
Processing

Steel Making and Shaping

Heat Treating
HEAT TREATING