Carbon and Alloy Steels

• All of these steels are alloys of Fe and C
  – Plain carbon steels (less than 2% carbon and negligible amounts of other residual elements)
    • Low Carbon (less than 0.3% carbon)
    • Med Carbon (0.3% to 0.6%)
    • High Carbon (0.6% to 0.95%)
  – Low Alloy Steel
  – High Alloy Steel
  – Stainless Steels (Corrosion-Resistant Steels)
    – contain at least 10.5% Chromium
AISI - SAE Classification System

American Iron and Steel Institute (AISI)

• classifies alloys by chemistry

• 4 digit number
  – 1st number is the major alloying element
  – 2nd number designates the subgroup alloying element OR the relative percent of primary alloying element.
  – last two numbers approximate amount of carbon (expresses in 0.01%)
Plain Carbon Steel

Plain Carbon Steel

• Lowest cost
• Should be considered first in most application
• 3 Classifications
  • Low Carbon (less than 0.3% carbon)
  • Med Carbon (0.3% to 0.6%)
  • High Carbon (0.6% to 0.95%)
Plain Carbon Steel

• Again, alloy of iron and carbon with carbon the major strengthening element via solid solution strengthening.

• If carbon level high enough (greater than 0.6%) can be quench hardened (aka: dispersion hardening, through hardened, heat treated, austenitized and quenched, etc..).

• Can come in HRS and CRS options

• The most common CRS are 1006 through 1050 and 1112, 1117 and other free machining steels
Plain Carbon Steel

1. Low Carbon (less than 0.3% carbon)
   • Low strength, good formability
     • If wear is a potential problem, can be carburized (diffusion hardening)
     • Most stampings made from these steels
     • AISI 1008, 1010, 1015, 1018, 1020, 1022, 1025

2. Med Carbon (0.3% to 0.6%)
   • Have moderate to high strength with fairly good ductility
   • Can be used in most machine elements
   • AISI 1030, 1040, 1050, 1060*

3. High Carbon (0.6% to 0.95%)
   • Have high strength, lower elongation
   • Can be quench hardened
   • Used in applications where surface subject to abrasion – tools, knives, chisels, ag implements.
   • AISI 1080, 1095
Trends?
Increasing carbon content – tensile strength increases, elongation decreases.
Alloy Steel

• Other elements (besides carbon) can be added to iron to improve mechanical property, manufacturing, or environmental property.

• Example: sulfur, phosphorous, or lead can be added to improve machine ability.
  – Generally want to use for screw machine parts or parts with high production rates!
  – Examples: 11xx, 12xx and 12Lxx
Alloy Steel

• Again, elements added to steel can dissolve in iron (solid solution strengthening):
  – Increase strength, hardenability, toughness, creep, high temp resistance.

• Alloy steels grouped into low, med and high-alloy steels.
  – High-alloy steels would be the stainless steel groups.
  – Most alloy steels you’ll use fall under the category of low alloy.
Alloy Steel

• > 1.65%Mn, > 0.60% Si, or >0.60% Cu

• Most common alloy elements:
  – Chromium, nickel, molybdenum, vanadium, tungsten, cobalt, boron, and copper.

• Low alloy: Added in small percents (<5%)
  – increase strength and hardenability

• High alloy: Added in large percents (>20%)
  – i.e. > 10.5% Cr = stainless steel where Cr improves corrosion resistance and stability at high or low temps
Alloying Elements used in Steel

**Manganese (Mn)**

- combines with sulfur to prevent brittleness
- >1%  
  - increases hardenability
- 11% to 14%  
  - increases hardness  
  - good ductility  
  - high strain hardening capacity  
  - excellent wear resistance
- Ideal for impact resisting tools
Alloying Elements used in Steel

**Sulfur (S)**

- Imparts brittleness
- Improves machineability
- Okay if combined with Mn
- Some free-machining steels contain 0.08% to 0.15% S
- Examples of S alloys:
  - 11xx – sulfurized (free-cutting)
Alloying Elements used in Steel

**Nickel (Ni)**

- Provides strength, stability and toughness.

Examples of Ni alloys:
- 30xx – Nickel (0.70%), chromium (0.70%)
- 31xx – Nickel (1.25%), chromium (0.60%)
- 32xx – Nickel (1.75%), chromium (1.00%)
- 33XX – Nickel (3.50%), chromium (1.50%)
Alloying Elements used in Steel

Chromium (Cr)

- Usually < 2%
- Increase hardenability and strength
- Offers corrosion resistance by forming stable oxide surface
- Typically used in combination with Ni and Mo
  - 30XX – Nickel (0.70%), chromium (0.70%)
  - 5xxx – chromium alloys
  - 6xxx – chromium-vanadium alloys
  - 41xxx – chromium-molybdenum alloys

Molybdenum (Mo)

- Usually < 0.3%
- Increase hardenability and strength
- Mo-carbides help increase creep resistance at elevated temps
  - Typical application is hot working tools
Alloying Elements used in Steel

**Vanadium (V)**
- Usually 0.03% to 0.25%
- increase strength
  - without loss of ductility

**Tungsten (W)**
- helps to form stable carbides
- increases hot hardness
  - used in *tool steels*
Alloying Elements used in Steel

**Copper (Cu)**
- 0.10% to 0.50%
- increase corrosion resistance
- **Reduced** surface quality and hot-working ability
- used in low carbon sheet steel and structural steels

**Silicon (Si)**
- About 2%
- increase strength **without** loss of ductility
- enhances magnetic properties
Alloying Elements used in Steel

**Boron (B)**
- for low carbon steels, can drastically increase hardenability
- improves machinability and cold forming capacity

**Aluminum (Al)**
- deoxidizer
- 0.95% to 1.30%
- produce Al-nitrides during nitriding
Tool Steel

- Refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools.
- Characteristics include high hardness, resistance to abrasion (excellent wear), an ability to hold a cutting edge, resistance to deformation at elevated temperatures (red-hardness).
- Tool steel are generally used in a heat-treated state.
- High carbon content – very brittle