



Outline

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- Stainless Steels
 - Ferritic SS
 - Austenitic SS
 - Martensitic SS
 - Precipitation Hardenable SS
- Cast Irons
 - Gray CI
 - Ductile CI
 - White CI
 - Malleable CI

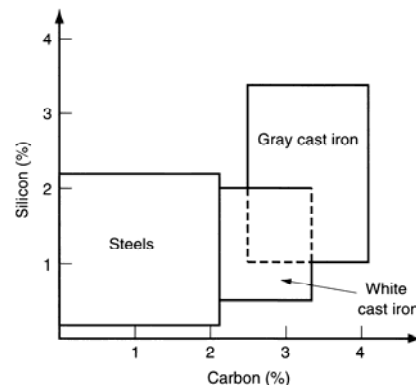


Introduction: Ferrous alloys - Review

- AISI-SAE designation uses a 4-digit number system: YYXX, where YY indicates alloying elements, and XX indicates carbon % in hundredths of % points
- ✓ Examples:
 - 13XX - Manganese steel
 - 20XX - Nickel steel
 - 31XX - Nickel-chrome steel
 - 40XX - Molybdenum steel
 - 41XX - Chrome-molybdenum steel



Introduction: Ferrous alloys



Carbon and silicon % for cast irons, in comparison to steels

- Most steels have relatively low Si % - cast steels have higher Si %.
- **Ductile iron** is formed by special melting and pouring treatment of **gray cast iron**, and **malleable iron** is formed by heat treatment of **white cast iron**.

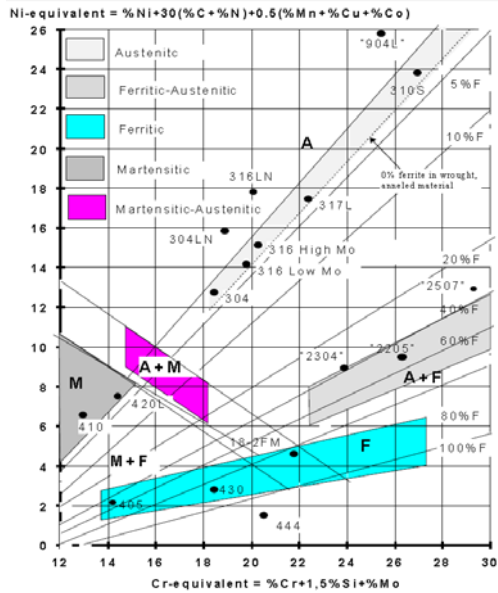


Stainless Steels

- Primary Factor: Corrosion Resistance
 - Corrosion Resistance is due to at least 11% chromium addition.*
 - $4 \text{ Cr} + 3 \text{ O}_2 \rightarrow 2 \text{ Cr}_2\text{O}_3$ This thin surface oxide protects metals underneath.
- Ni is another alloying ingredient in certain SS to increase corrosion protection
- Carbon is used to strengthen SS, but high C content reduces corrosion protection since chromium carbide forms to reduce available free Cr.
- In addition to corrosion resistance, stainless steels are noted for their combination of and
 - While desirable in many applications, these properties generally make SS difficult to work in manufacturing
- Significantly more expensive than plain C or low alloy steels
- Classified according to the predominant phase present at ambient temp.:
 1. **Austenitic stainless** - typical composition 18% Cr and 8% Ni
 2. **Ferritic stainless** - about 15% to 20% Cr, low C, and no Ni
 3. **Martensitic stainless** - as much as 18% Cr but no Ni, higher C content than ferritic stainless



Stainless Steels: The Schaeffler-Delong diagram



Stainless Steels

Ferritic Stainless Steels:

- 11 to 30% Cr & less than **0.2%C**; → BCC,
- good strengths (cold-working),
- moderate ductilities,
- good **corrosion resistance**
- relatively inexpensive (*4x low-C steel*)
- magnetic.

Table 12.4 Designations, Compositions, Mechanical Properties, and Typical Applications for Austenitic, Ferritic, Martensitic, and Precipitation-Hardenable Stainless Steels

AISI Number	UNS Number	Composition (wt%)*	Condition ^b	Mechanical Properties			Typical Applications
				Tensile Strength [MPa (ksi)]	Yield Strength [MPa (ksi)]	Ductility [%EL in 50 mm (2 in.)]	
Ferritic							
409	S40900	0.08 C, 11.0 Cr, 1.0 Mn, 0.50 Ni, 0.75 Ti	Annealed	380 (55)	205 (30)	20	Automotive exhaust components, tanks for agricultural sprays
446	S44600	0.20 C, 25 Cr, 1.5 Mn	Annealed	515 (75)	275 (40)	20	Valves (high temperature), glass molds, combustion chambers



Stainless Steels

Austenitic Stainless Steels:

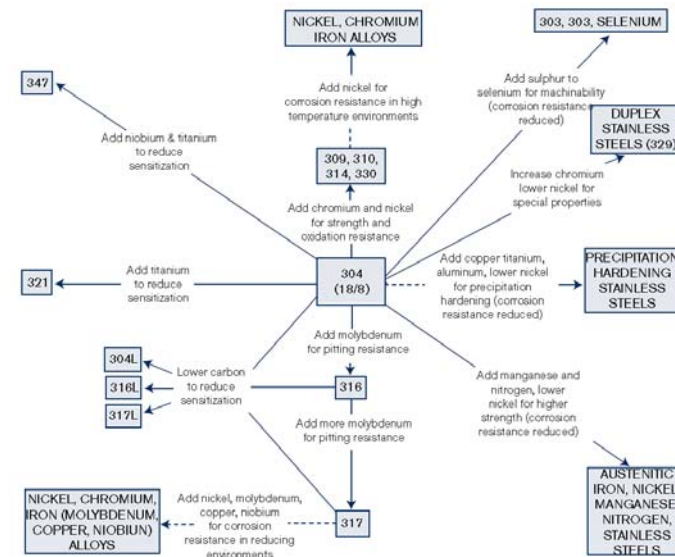
- FCC, (Cr + Nickel...),
- excellent formability & ductility, cold-working,
- no DBTT,
- not ferromagnetic.
- relatively expensive (*6-9x low C steel*).

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Austenitic							
304	S30400	0.08 C, 19 Cr, 9 Ni, 2.0 Mn	Annealed	515 (75)	205 (30)	40	Chemical and food processing equipment, cryogenic vessels
316L	S31603	0.03 C, 17 Cr, 12 Ni, 2.5 Mo, 2.0 Mn	Annealed	485 (70)	170 (25)	40	Welding construction



Some Compositional Modifications of 18/8 Austenitic Stainless steel to produce special properties





Stainless Steels

Martensitic Stainless Steels:

- Cr less than 17%, between 0.1 and 1% C,
 - hence can be heat treated to give martensite - BCT,
- high hardness & strength
- corrosion resistance
- magnetic.

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Martensitic							
410	S41000	0.15 C, 12.5 Cr, 1.0 Mn	Annealed Q & T	485 (70) 825 (120)	275 (40) 620 (90)	20 12	Rifle barrels, cutlery, jet engine parts
440A	S44002	0.70 C, 17 Cr, 0.75 Mo, 1.0 Mn	Annealed Q & T	725 (105) 1790 (260)	415 (60) 1650 (240)	20 5	Cutlery, bearings, surgical tools



Stainless Steels

Precipitation Hardenable Stainless Steels:

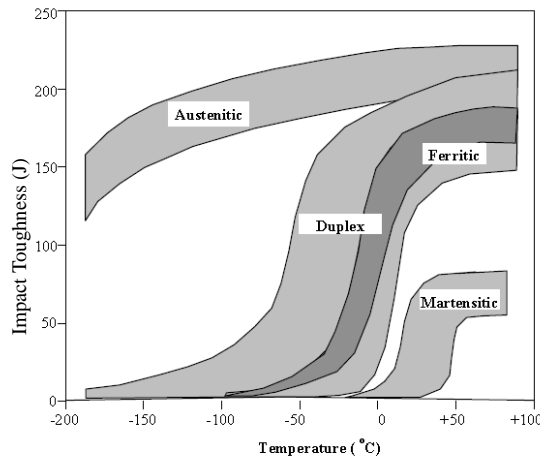
- Strengthening is accomplished by precipitation-hardening heat treatment
- e.g. 17-7PH → Cr 17% and Ni 7%
- ultrahigh strength
- corrosion resistance

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Precipitation Hardenable							
17-7PH	S17700	0.09 C, 17 Cr, 7 Ni, 1.0 Al, 1.0 Mn	Precipitation hardened	1450 (210)	1310 (190)	1-6	Springs, knives, pressure vessels



Impact Toughness of Different Types of Stainless Steels



Toughness is on temperature and generally increases with increasing temperature.

The toughness of the different types of stainless steels shows considerable variation, ranging from excellent toughness at all temperatures for the to the relatively brittle behaviour of the martensitic steels.



Cast Irons

➤ Generally Cast irons have high carbon levels. (2 - 4.5% C) and (0.5 - 3.0% Si)

- Carbon can either be present as:
 - Fe₃C (*carbide*) → metastable or
 - C (*graphite*) → stable

- Phase diagram is very similar to Fe-Fe₃C diagram - only slight changes - swap graphite for Fe₃C.
- However some cast irons have both Fe₃C and Graphite!
- Graphite formation favoured by silicon and slower cooling rates.

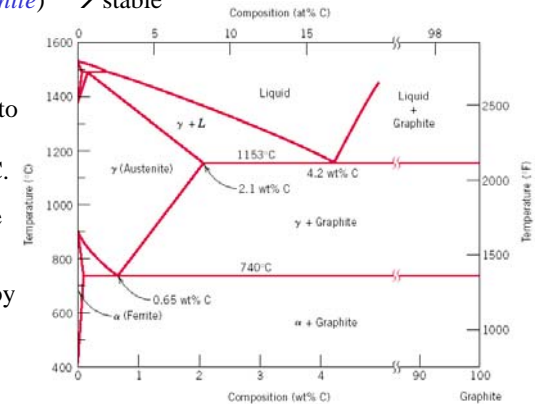


FIGURE 12.5 The true equilibrium PD of Fe-C with graphite instead of cementite as a stable phase.



Cast Irons

- Intended for casting into final shape (no hot/cold working, only final machining)
- Easily melted (~ eutectic)
- Very fluid (run well) (~ eutectic)
- Clean surface
- Low shrinkage
- Range of strengths, hardnesses etc.
- Relatively cheap.
- But usually low & very low

Four main types:

- Gray Iron
- Ductile or Nodular Iron
- White Iron
- Malleable Iron



Gray Cast Iron

- (2 - 4.5% C) and (1.0 – 3.0% Si)
 - Most common.
 - Graphite precipitates as **GRAPHITE FLAKES**.
 - Weak in tension
 - Brittle (*graphite flakes act as sharp stress concentrators*)
 - Good for compressive loading
 - Machinable,
 - Wear resistant,
 - **Good**
 - High fluidity
 - CHEAP !
- ✓ Engine blocks and machine tool bases, drain covers... etc



Slow cooling → Graphite flakes in FERRITE MATRIX
 Faster cooling → Graphite flakes in PEARLITIC MATRIX



Gray Cast Iron

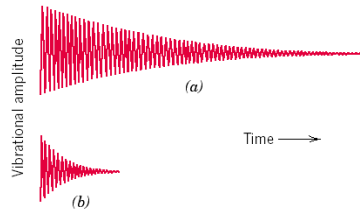


FIGURE 12.7 Comparison of the relative vibrational damping capacities of (a) steel and (b) gray cast iron. (From *Metals Engineering Quarterly*, February 1961. Copyright 1961 American Society for Metals.)

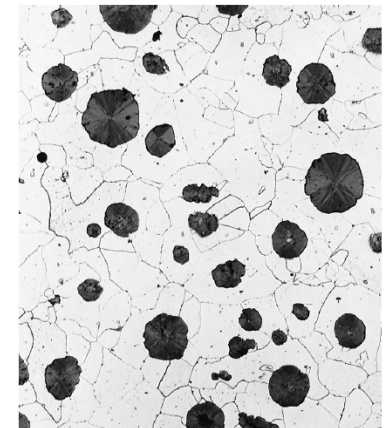
Table 12.5 Designations, Minimum Mechanical Properties, Approximate Compositions, and Typical Applications for Various Gray, Nodular, and Malleable Cast Irons

Grade	UNS Number	Composition (wt%) ^a	Matrix Structure	Mechanical Properties			Typical Applications
				Tensile Strength [MPa (ksf)]	Yield Strength [MPa (ksf)]	Ductility [%EL in 50 mm (2 in.)]	
Gray Iron							
SAE G1800	F10004	3.40–3.7 C, 2.55 Si, 0.7 Mn	Ferrite + Pearlite	124 (18)	—	—	Miscellaneous soft iron castings in which strength is not a primary consideration
SAE G2500	F10005	3.2–3.5 C, 2.20 Si, 0.8 Mn	Ferrite + Pearlite	173 (25)	—	—	Small cylinder blocks, cylinder heads, pistons, clutch plates, transmission cases
SAE G4000	F10008	3.0–3.3 C, 2.0 Si, 0.8 Mn	Pearlite	276 (40)	—	—	Diesel engine castings, liners, cylinders, and pistons



Ductile Cast Iron

- **NODULAR** or **DUCTILE** Cast Iron (**USA**)
- spheroidal graphite cast iron - s.g. iron (*in UK and Europe*)
- Promote graphite to form spherical nodules (rather than flakes) by adding **magnesium** or **cerium** etc (*to reduce S + P levels*)
- Graphite nodules in envelopes of ferrite, all surrounded by pearlitic and/or ferritic matrix if heat treated.





Ductile Cast Iron

- Much better overall mechanical properties than other cast irons.
 - Good fluidity & castability
 - Good machinability
 - Good wear resistance & High strength
 - **Relatively High**
 - **Hot workability** & hardenability
 - More expensive than grey cast iron.
- ✓ Valves, pump bodies, crankshafts, gears etc.

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<i>Ductile (Nodular) Iron</i>							
ASTM A536 60-40-18	F32800	3.5–3.8 C, 2.0–2.8 Si, 0.05 Mg, <0.20 Ni, <0.10 Mo	Ferrite	414 (60)	276 (40)	18	Pressure-containing parts such as valve and pump bodies
100-70-03	F34800		Pearlite	689 (100)	483 (70)	3	High-strength gears and machine components
120-90-02	F36200		Tempered martensite	827 (120)	621 (90)	2	Pinions, gears, rollers, slides



White Cast Iron

- Mainly iron carbides (Fe_3C) in a PEARLITIC MATRIX.
- To ensure carbides form instead of graphite → relatively low carbon and low silicon contents (<1%) + **faster cooling**.
- Outer surface may be **W.C.I** whilst inner regions that cool slower may be **G.C.I**.
- Lots of carbides so very hard.
- Used for **WEAR RESISTANCE**.
- Virtually un-machinable. (brittle)

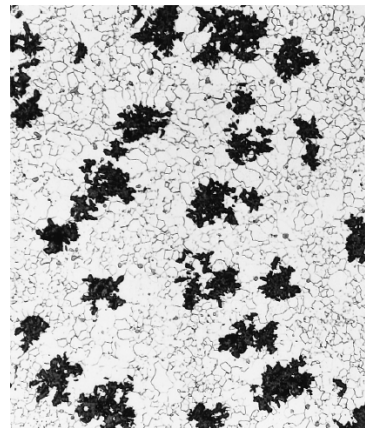


- ✓ Rolls for rolling mill



Malleable Cast Iron

- **White cast** iron is heat treated ($\approx 940^\circ C$) to promote graphitization of the iron carbide into graphite rosettes (*popcorn*)
- By controlling the heat treatment and cooling can get:
 - Ferritic structures
 - Pearlitic structures
 - Martensitic structures



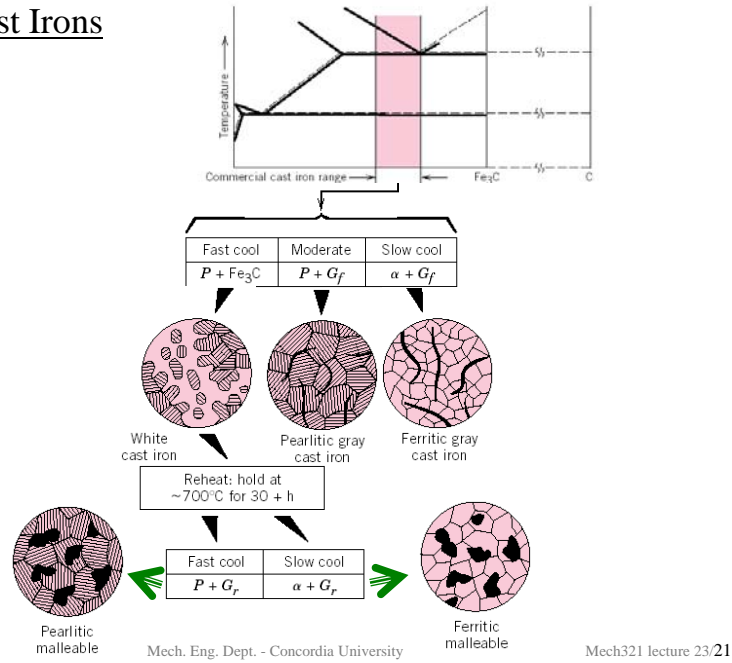
Malleable Cast Iron

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<i>Malleable Iron</i>							
32510	F22200	2.3–2.7 C, 1.0–1.75 Si, <0.55 Mn	Ferrite	345 (50)	224 (32)	10	General engineering service at normal and elevated temperatures
45006	—	2.4–2.7 C, 1.25–1.55 Si, <0.55 Mn	Ferrite + Pearlite	448 (65)	310 (45)	6	



Cast Irons



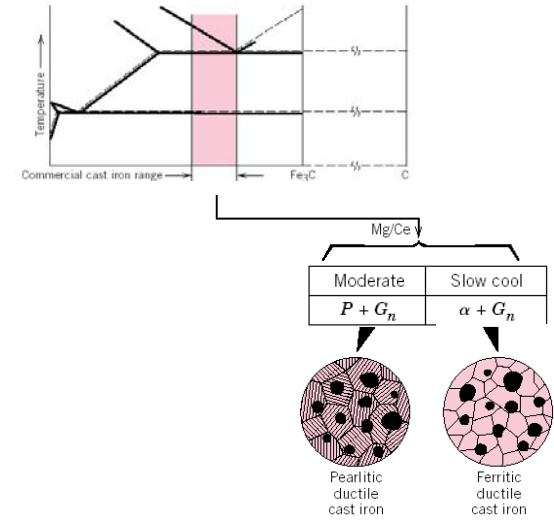
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Mech321 lecture 23/21



Cast Irons



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*Next time:
Nonferrous Alloys*

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