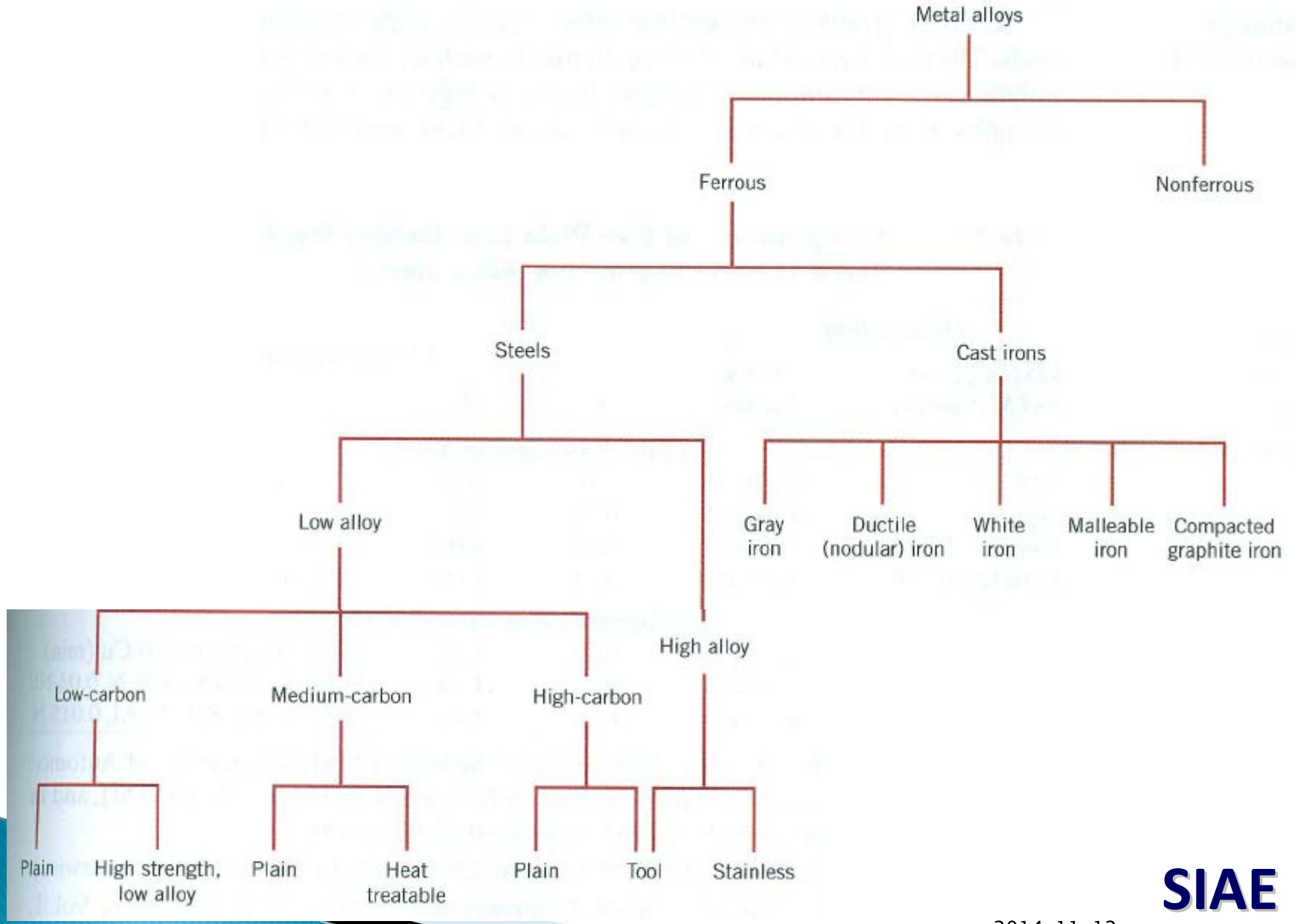
8. Ferrous metals

Structural metallic materials



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Structural metallic materials

Ferrous alloys widespread use is accounted for by three factors:

(1)Iron-containing compounds exist in abundant quantities within the earth's crust

(2)Metallic iron and steel alloys may be produced using relatively economical extraction, refining, alloying, and fabrication techniques

(3)Ferrous alloys are extremely versatile, in that they may be tailored to have a wide range of mechanical and physical properties

Structural metallic materials

8.1 STEELS

- Low-Carbon Steels
- medium-Carbon Steels
- High-Carbon Steels

Plain carbon steel: A ferrous alloy in which carbon is the prime alloying element

alloy steel: A ferrous (or iron-based) alloy that contains appreciable concentrations of alloying elements. These alloying elements are usually added to improve mechanical and corrosion-resistance properties.

Structural metallic materials

8.1.1 Low-Carbon Steels (low alloy)

- These generally contain less than about 0.25wt%C
- Unresponsive to heat treatments
- Strengthening is accomplished by cold work
- Microstructures consist of ferrite and pearlite

Disadvantage:

- Soft
- weak

Structural metallic materials

advantage:

- ductility
- Toughness
- Machinable
- Weldable
- inexpensive

Application:

- Automobile body components
- Structural shapes
- Sheets

Structural metallic materials

High-strength, low-alloy(HSLA)steels : relatively strong, low-carbon steels, with less than about to wt% total of alloying elements

AISI : American Iron and Steel Institute
SAE: the Society of Automotive Engineers
ASTM: American Society for Testing and Materials
UNS： the Uniform Numbering System

Structural metallic materials

STEELS

Low-Carbon Steels

Compositions of Five Plain Low-Carbon Steels and Three High-Strength, Low-Alloy Steels

Designation[a]		Composition(wt%)[b]		
AISI/SAE or ASTM Number	UNS Number	C	Mn	Other
Plain Low-Carbon Steels				
1010	G10100	0.10	0.45	
1020	G10200	0.20	0.45	
A36	K02600	0.29	1.00	0.20Cu(min)
A516 Grade 70	K02700	0.31	1.00	0.25Si
High- Strength, Low-Alloy Steels				
A440	K12810	0.28	1.35	0.30 Si(max), 0.20Cu(min)
A633 Grade E	K12002	0.22	1.35	0.30Si, 0.08V, 0,02N,0.03Nb
A656 Grade 1	K11804	0.18	1.60	0.60Si, 0.1V, 0.20Al, 0.015N

Structural metallic materials

Low-Carbon Steels

Mechanical Characteristics of Hot-Rolled Material and Typical Applications for Various Plain Low-Carbon and High-Strength, Low-Alloy Steels

AISI/SAE or ASTM Number	*Tensile Strength [MPa (ksi)]*	*Yield Strength [MPa (ksi)]*	*Ductility [%EL in 50 mm (2 in.)]*	*Typical Applications*
		Plain Low-Carbon Steels		
1010	325 (47)	180 (26)	28	Automobile panels, nails, and wire
1020	380 (55)	210 (30)	25	Pipe; structural and sheet steel
A36	400 (58)	220 (32)	23	Structural (bridges and buildings)
A516 Grade 70	485 (70)	260 (38)	21	Low-temperature pressure vessels
		High-Strength, Low-Alloy Steels		
A440	435 (63)	290 (42)	21	Structures that are bolted or riveted
A633 Grade E	520 (75)	380 (55)	23	Structures used at low ambient temperatures
A656 Grade 1	655 (95)	552 (80)	15	Truck frames and railway cars

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Structural metallic materials

8.1.2 Medium-Carbon Steels (low alloy)

- These generally contain less than about 0.25-0.60wt%C
- heat treatments by austenitizing, quenching
- Microstructures consist of martensite

Application:

- Railway wheels and tracks
- gear
- Crankshafts
- Other machine part

Structural metallic materials

STEELS

Medium-Carbon Steels

AISI/SAE and UNS Designation Systems and Composition Ranges for Plain Carbon Steels and Various Low-Alloy Steels

AISI/Designation[a]	UNS Designaition	Composition Ranges (wt% of Alloying Elements in Addition to C)[b]			
		Ni	Cr	Mo	Other
10XX,Plain carbon	G10xx0				
11XX,Free machining	G11xx0				0.08-0.33S
12XX,Free machining	G12xx0				0.10-0.35S
					0.04-0.12P
13XX	G13xx0				1.60-1.90Mn
40XX	G40xx0			0.20-0.30	
41XX	G41xx0		0.80-1.10	0.15-0.25	
43XX	G43xx0	1.65-2.00	0.40-0.90		
46XX	G46xx0	0.70-2.00			
48XX	G48xx0	3.25-3.75			
51XX	G51xx0		0.70-1.10		
61XX	G61xx0		0.50-1.10		0.10-0.15V
86XX	G86xx0	0.40-0.70	0.40-0.60	0.15-0.25	
92XX	G92xx0				1.80-2.20Si

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Structural metallic materials

STEELS

Medium-Carbon Steels

Typical Applications and Mechanical Property for Oil-Quenched and Tempered Plain Carbon and Alloys Steels

UNS Number	Tensile Strength**(Mpa (ksi))**	**Yield Strength (Mpa(ksi))**	**Ductility(%EL in 50 mm (2in.)**	**Typical Applications**
Plain Carbon Steels				
G10400	605-780 (88-113)	430-585 (62-85)	33-19	Crankshafts, bolts
G10800	800-1310 (116-190)	480-980 (70-142)	24-13	Chisels, hammers
G10950	760-1280 (110-186)	510-830 (74-120)	26-10	Knives, hacksaw blades
Alloys Steels				
G40630	786-2380 (114-345)	710-1770 (103-257)	24-4	Springs, hand tools
G43400	980-1960 (142-284)	895-1570 (130-228)	21-11	Bushings, aircraft tubing
G61500	815-2170 (118-315)	745-1860 (108-270)	22-7	Shafts, pistons, gears

Structural metallic materials

8.1.3 High-Carbon Steels (low alloy)

- These generally contain less than about 0.6-1.4wt%C
- heat treatments by austenitizing, quenching
- Microstructures consist of martensite

advantage:

- Hard
- Strong
- Wear resistant
- Good cutting performance

Structural metallic materials

Application:

- knives
- razors
- Hacksaw blades
- Spring
- High-strength wire

Structural metallic materials

STEELS

High-Carbon Steels

Designations, Compositions, and Applications for Six Tool Steels

UNS Number	Compositions(**(wt%)**[a]						**Typical Applications**
	C	Cr	Ni	Mo	W	V	
T11301	0.85	3.75	0.30max	8.70	1.75	1.20	Drills, saws, lathe and planer tools
T30102	1.00	5.15	0.30max	1.15		0.35	Punches, embossing dies
T30402	1.50	12	0.30max	0.95		1.10max	Cutlery, drawing dies
T31501	0.95	0.50	0.30max		0.50	0.30max	Shear blades, cutting tools
T41901	0.50	1.40	0.30max	0.50max	2.25	0.25	Pipe cutters, concrete drills
T72301	1.10	0.15 max	0.20max	0.10max	0.15 max	0.10max	Blacksmith tools, woodworking tools

Structural metallic materials

8.1.4 Stainless Steels (high alloy)

Stainless steels : A steel alloy that is highly resistant to corrosion in a variety of environments. The predominant alloying element is chromium, which must be present in a concentration of at least 11wt%. Other alloy additions to include nickel and molybdenum, are also possible.

Stainless steels

- Martensitic-----magnetic
- ferritic-----magnetic
- Austenitic ------most corrosion resistant

Structural metallic materials

Application-resist oxidation:

- Gas turbines
- High-temperture steam boiler
- Heat-treating furnaces
- Aircraft
- Missiles
- Nuclear power-generating units

Structural metallic materials

STEELS

Stainless Steels

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

				Mechanical Properties			
AISI Number	UNS Number	Compositions(**(wt %)**[a]	Condition[b]	Tensile Strength**(Mpa(ksi))**	**Yield Strength (Mpa(ksi))**	**Ductility(%EL in 50 mm (2in.)**	**Typical Applications**
			Ferritic				
409	S40900	0.08C,11.0Cr,1.0 Mn,0.50Ni,0.75Ti	Annealed	380(55)	205(30)	20	Automotive exhaust component, tanks for agricultural spray
446	S44600	0.20C,25Cr,1.5M n	Annealed	515(75)	275(40)	20	Valves(high temperature), glass molds, combustion chambers
			Austenitic				
304	S30400	0.08C,19Cr,9Ni,2. 0Mn	Annealed	515(75)	205(30)	40	Chemical and food processing equipment, cryogenic vessels
316L	S31603	0.03C,17Cr,12Ni, 2.5Mo,2.0Mn	Annealed	485(70)	170(25)	40	Welding construction
			Martensitic				
410	S41000	0.15C,12.5Cr,1.0 Mn	Annealed Q&T	485(70) 825(120)	275(40) 620(90)	20 12	Rifle barrels, cutlery, jet engine parts
440A	S44002	0.70C,17Cr,0.75 Mo,1.0Mn	Annealed Q&T	725(105) 1790(260)	415(60) 1650(240)	20 5	Cutlery, bearings, surgical tools
			Precipitation Hardenable				
17-7PH	S17700	0.09C,17Cr,7Ni,1. 0Al,1.0Mn	Precipitatio-n hardened	1450(210)	1310(190)	1-6	Springs, knives, pressure vessels

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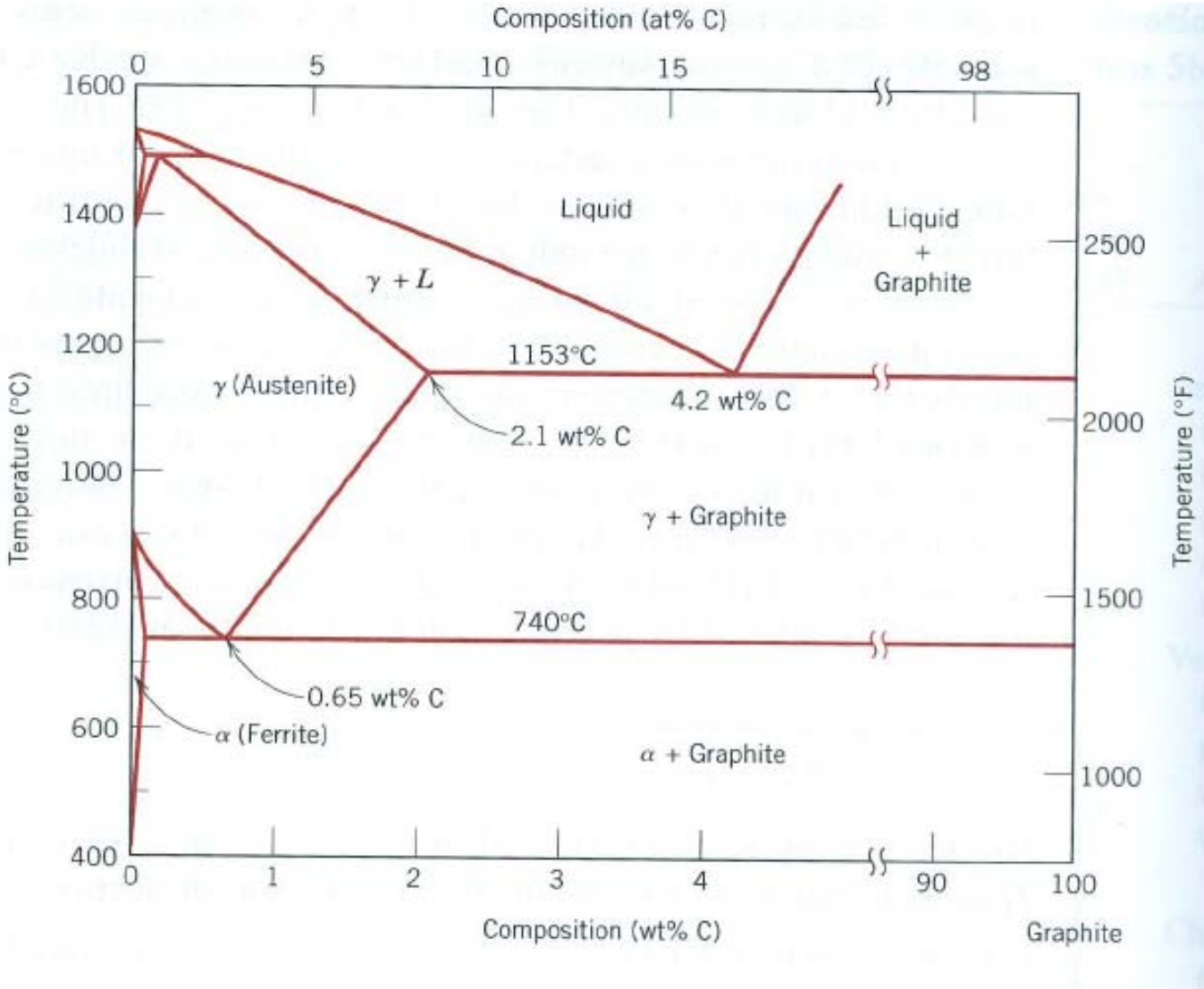
Structural metallic materials

8.2 Cast Irons

Cast Irons : Generically, a ferous alloy, the carbon content of which is greater than the maximum solubility in austenite at the eutectic temperature. Most commercial cast irons contain between 3.0 and 4.5 wt% C, and between 1and 3wt% Si.

Structural metallic materials

Cast Irons



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Structural metallic materials

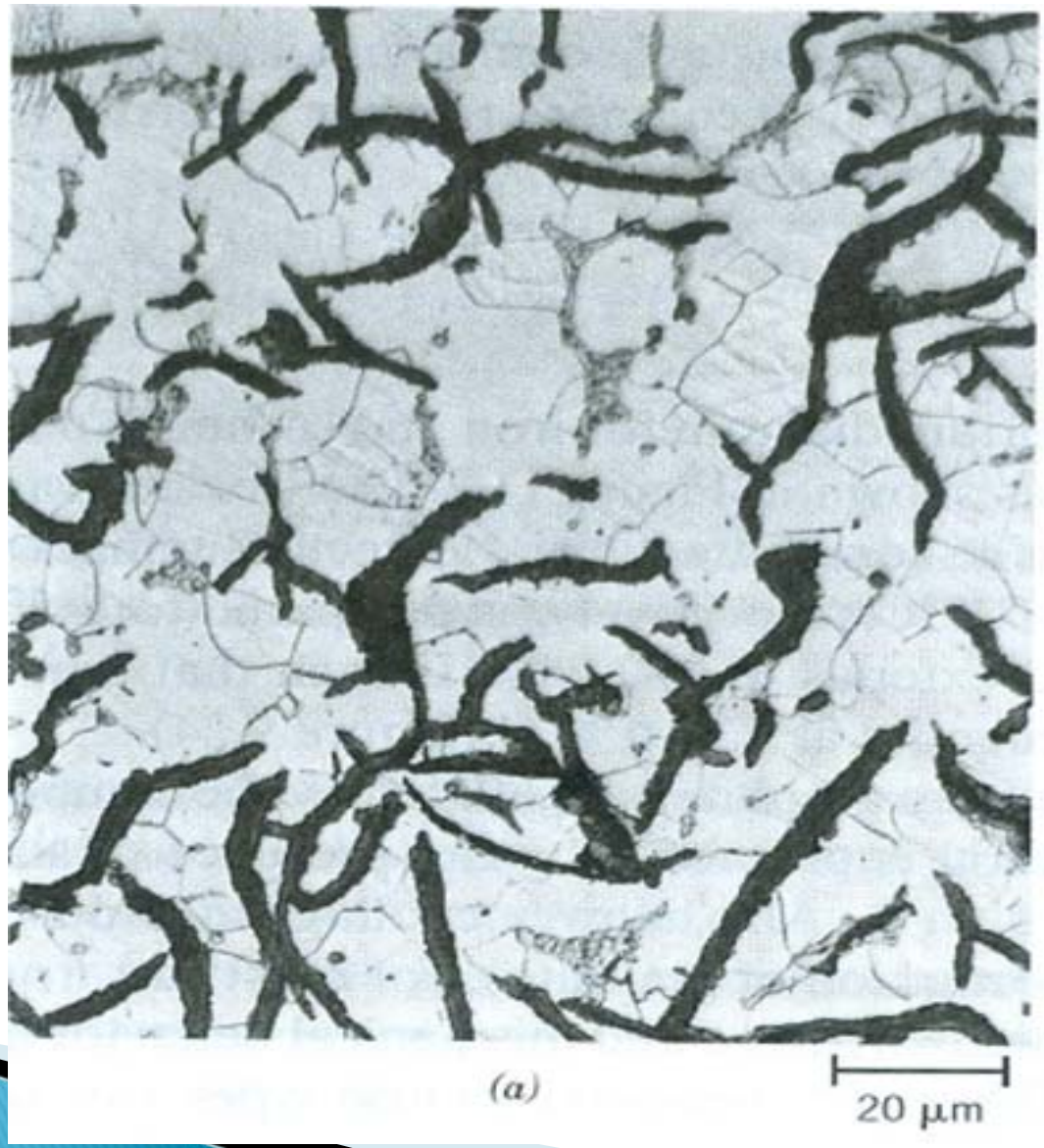
8.2.1 Gray Irons

Gray cast Irons : A cast iron alloyed with silicon in which the graphite exists in the form of flakes. A fractured surface appears gray.

- Brittle----sharp and point----stress concentration
- Damping vibrational energy
- Wear resistant
- High fluidty---casting---intricate shapes
- Least expensive

Structural metallic materials

Gray Iron



The dark graphite Flakes are embedded in an α -ferrite matrix

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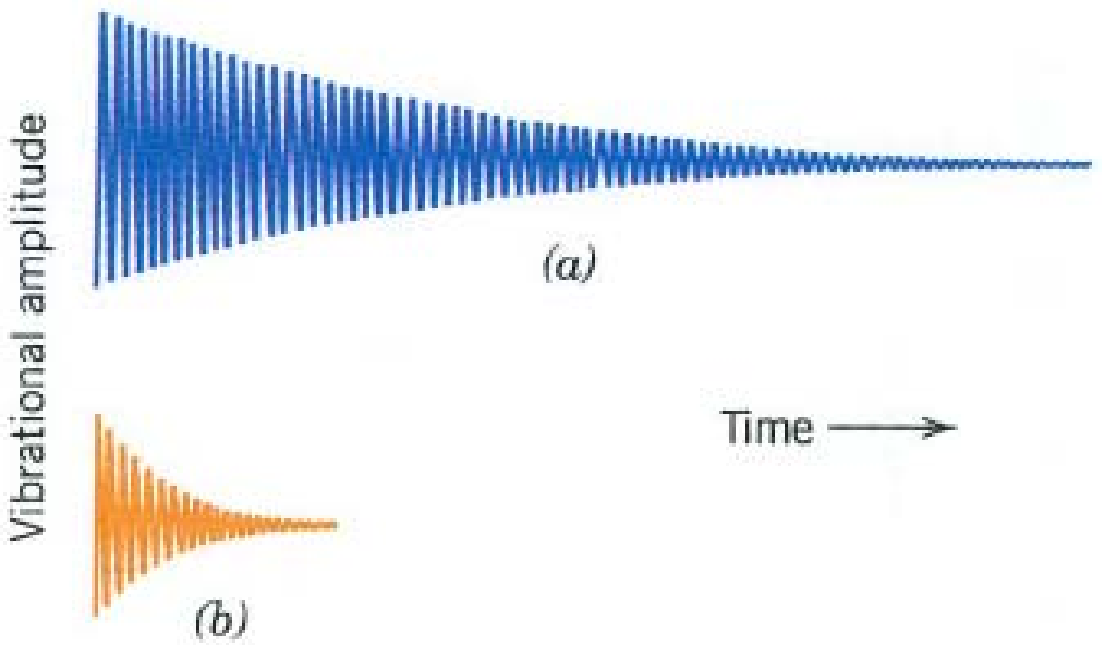
Structural metallic materials



Comparison of the relative vibrational damping capacities of (a)Steel and (b) gray cast iron

Structural metallic materials

8.2.2 Ductile Irons

Ductile (nodular) Irons: A cast iron that is alloyed with silicon and a small concentration of magnesium and/or cerium and in which the free graphite exists in nodular form. sometimes called nodular iron

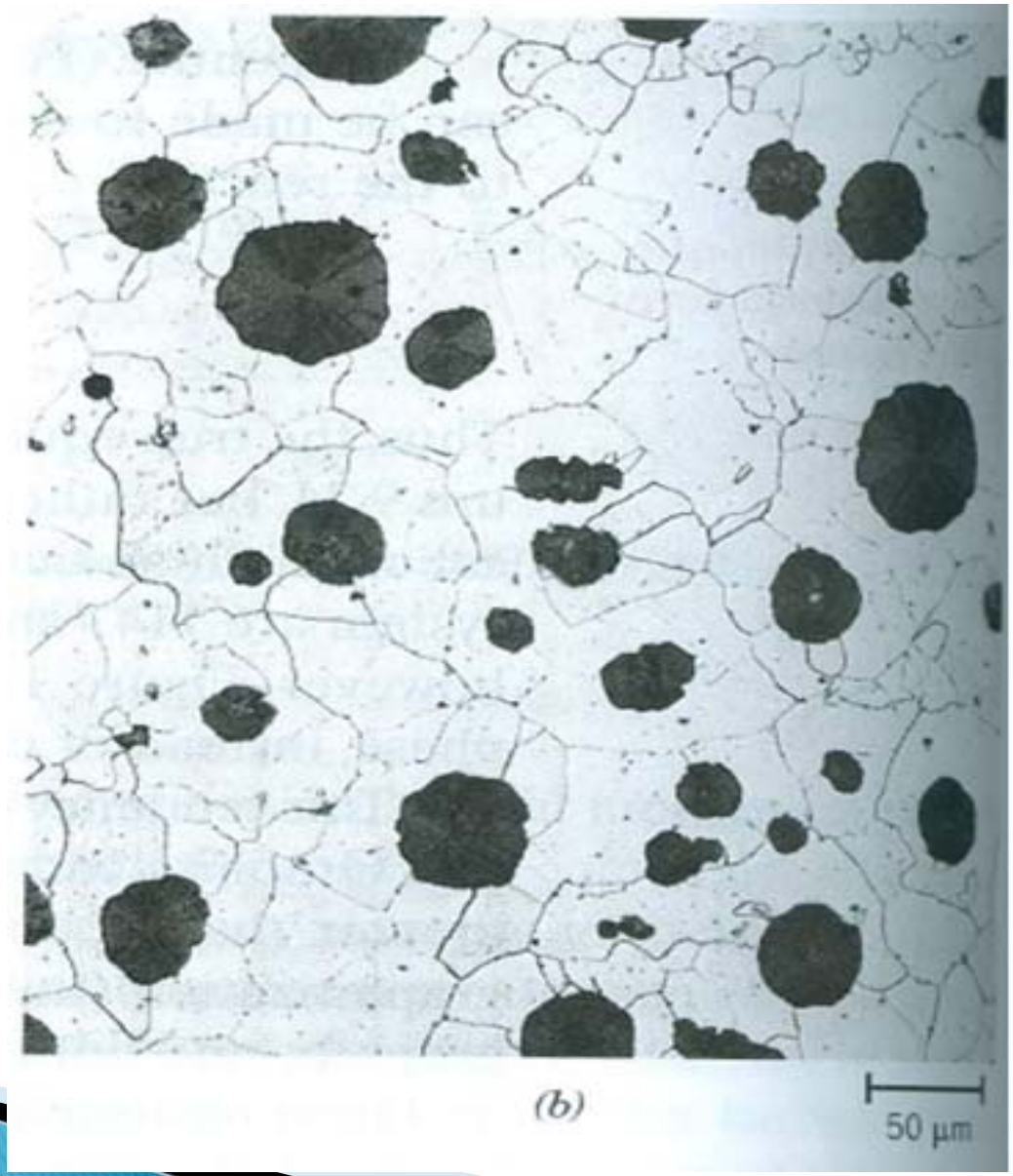
- Castings are stronger
- Much more ductile
- Mechanical characteristics approaching those of steel

Application:

- valves
- Pump bodies
- Crankshafts
- Gear
- Other automotive and machine components

Structural metallic materials

Ductile Iron



The dark graphite nodule are surrounded by an α -ferrite matrix

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Structural metallic materials

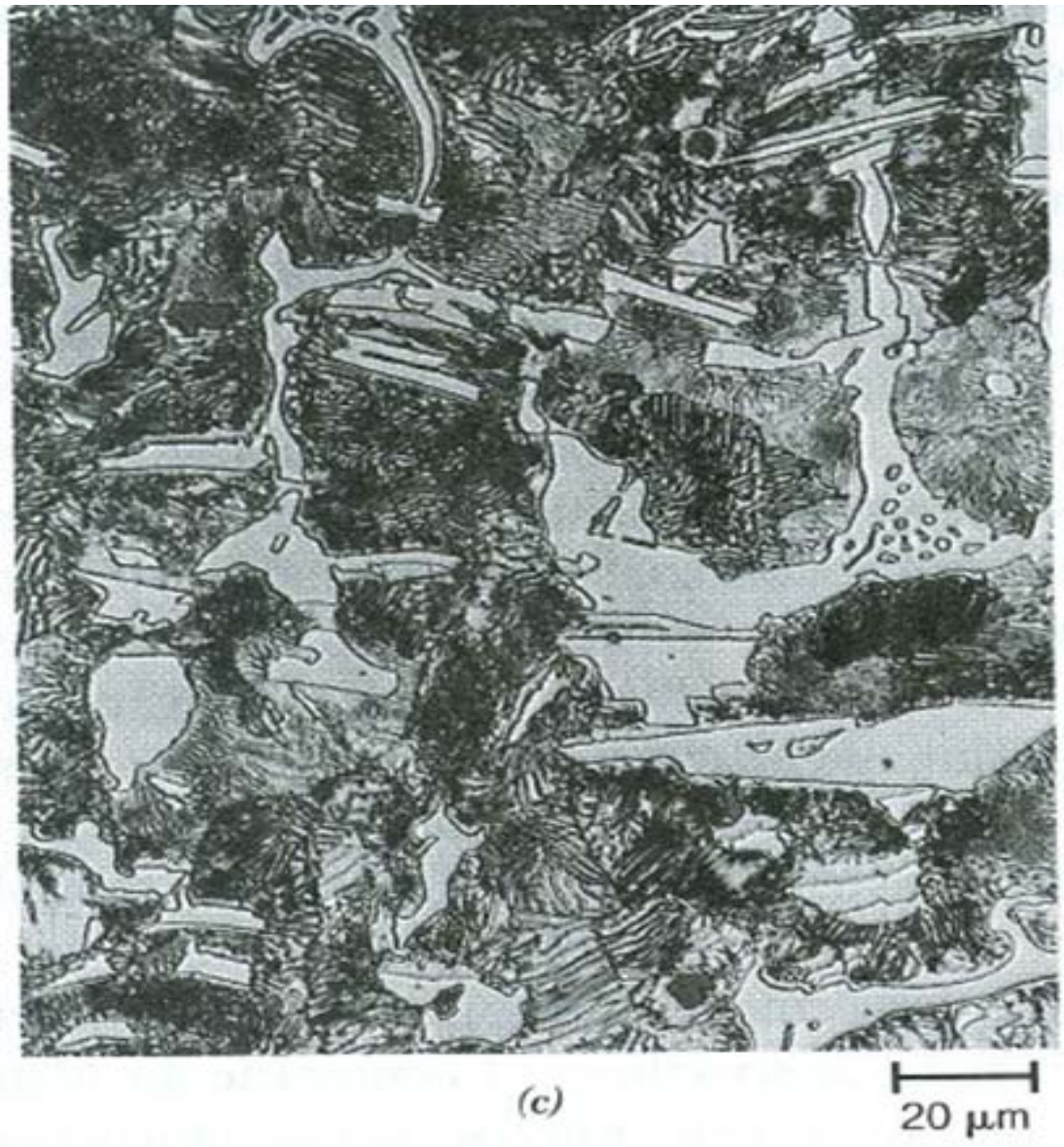
8.2.3 White cast Irons

White cast Irons: A low-silicon(1.0wt%) and very brittle cast iron in which the carbon is in combined form as cementite; a fractured surface appears white

- Very hard
- Very brittle
- Unmachinable

Structural metallic materials

White Iron



The light cementite Regions are surrounded By pearlite, which has the ferrite-cementitle Layered structure

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Structural metallic materials

8.2.4 Malleable Irons

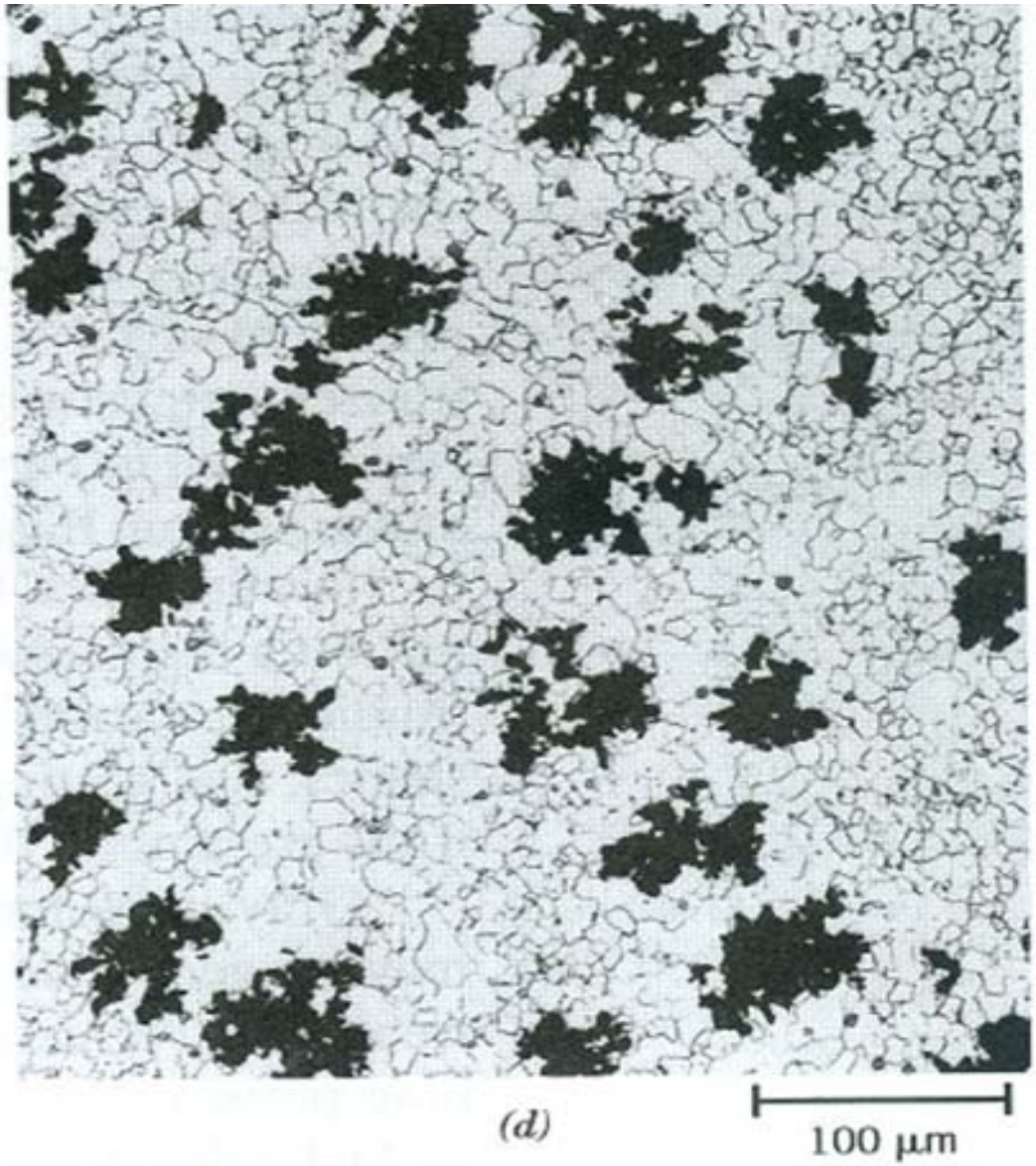
Malleable Irons: white cast iron that has been heat-treated to convert the cementite into graphite clusters; a relatively ductile cast iron.

Application:

- Connecting rods
- Transmission gears
- Automotive industry
- Pipe fitting
- Valve parts for railroad

Structural metallic materials

Malleable iron



Dark graphite Rosettes(temper carbon) in an α - ferrite matrix

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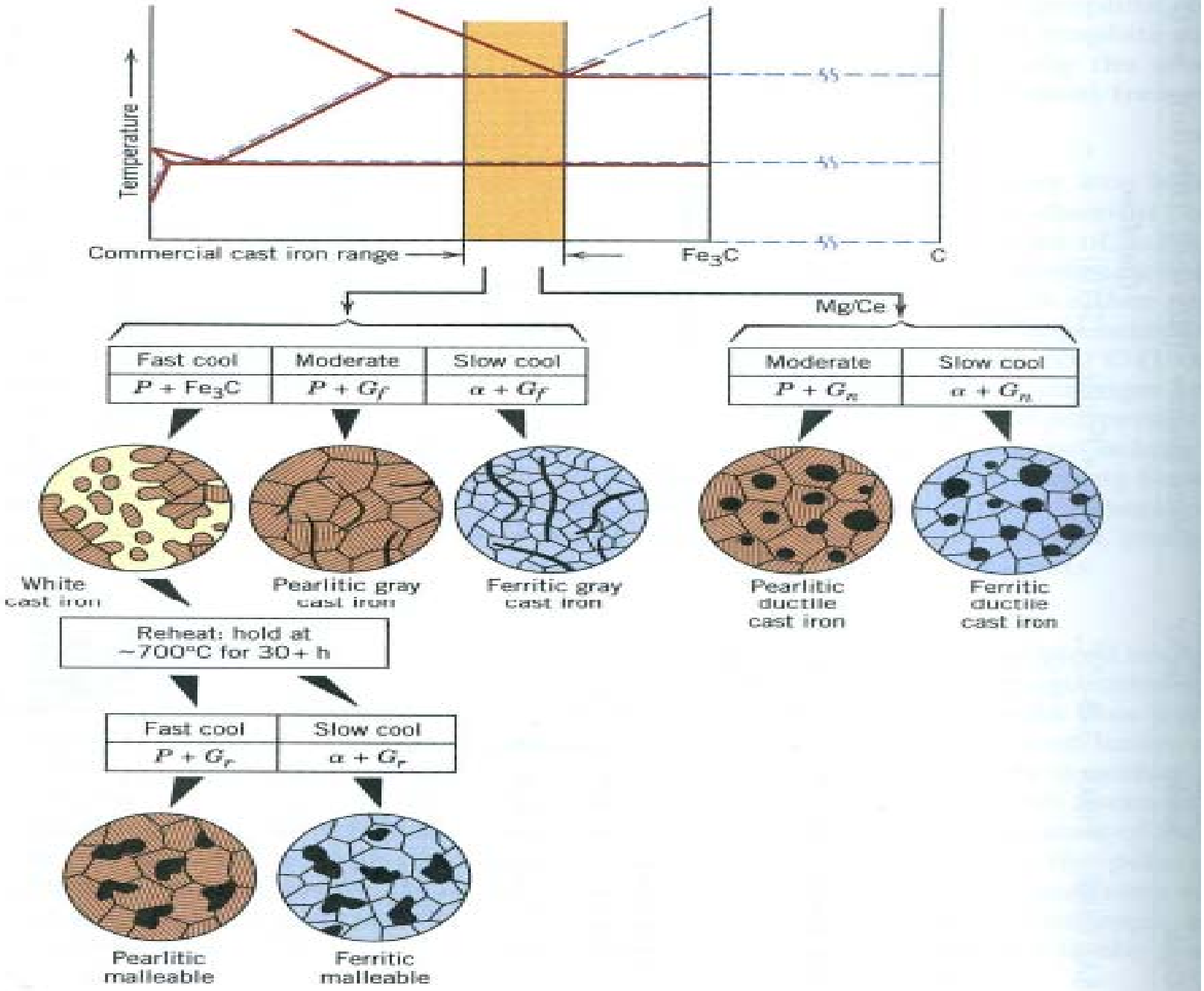

Temperature
Commercial cast iron range
Fe_3C
C
Mg/Ce
Fast cool
$P + Fe_3C$
Moderate
$P + G_f$
Slow cool
$\alpha + G_f$
Moderate
$P + G_n$
Slow cool
$\alpha + G_n$
White cast iron
Pearlitic gray cast iron
Ferritic gray cast iron
Pearlitic ductile cast iron
Ferritic ductile cast iron
Reheat: hold at ~700°C for 30+ h
Fast cool
$P + G_r$
Slow cool
$\alpha + G_r$
Pearlitic malleable
Ferritic malleable

Structural metallic materials

Gf---------flake graphite
Gr---------graphite rosettes
Gn--------graphite nodules
P-------PEARLITE
A -------FERRITE

Structural metallic materials

8.2.5 Compacted Graphite iron

Compacted Graphite iron

: A cast iron that is alloyed with silicon and a small amount of magnesium, cerium, or other additives, in which the graphite exists as wormlike particles.

C%=3.4%~3.6%； Si%=2.4%~3.0%；

Mn%=0.4%~0.6%； S%<0.06%； P%<0.07%。

Lower strengths

- Higher ductilities
- Tensile and ys better than gray irons

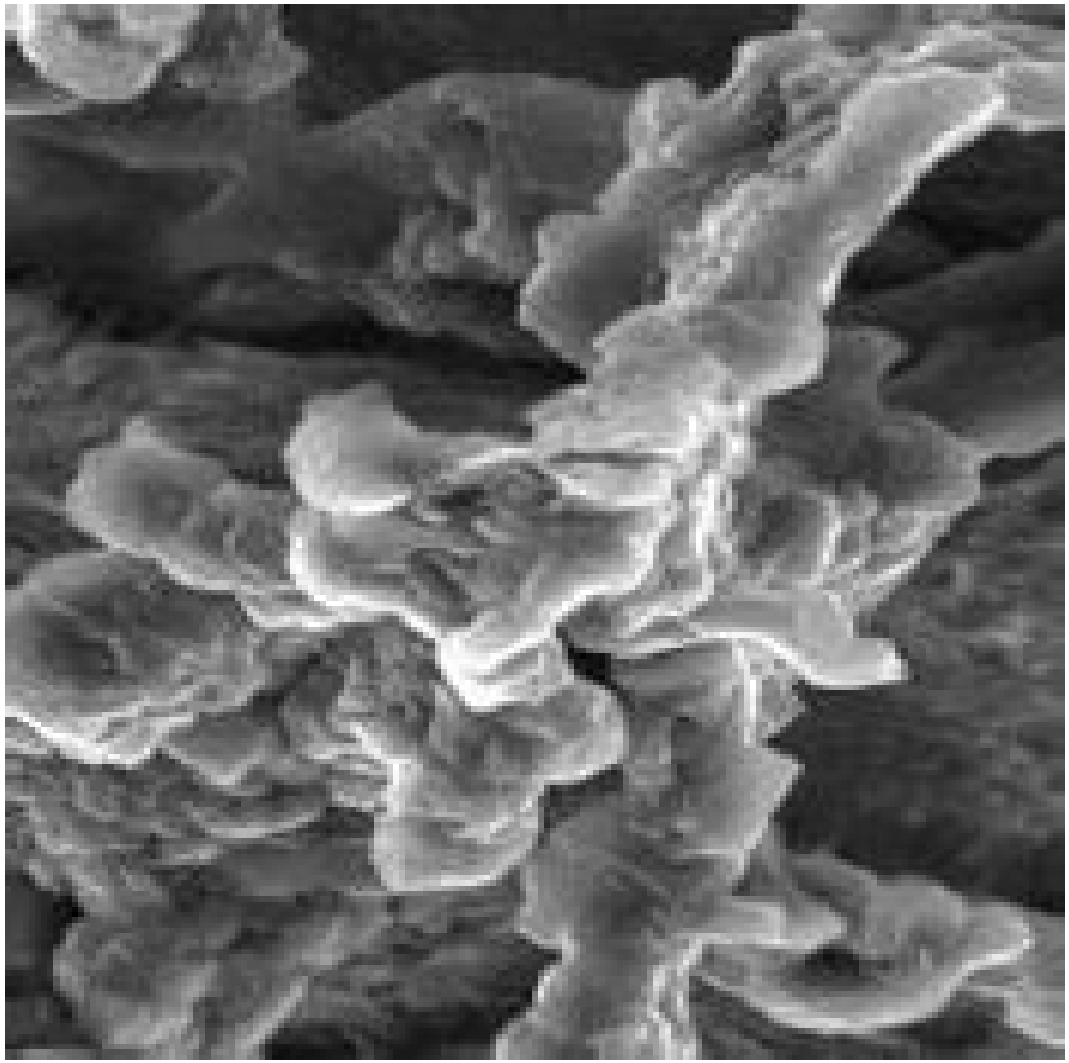
Structural metallic materials

Characteristics:

- Higher thermal conductivity
- Better resistance to thermal shock
- Lower oxidation at elevated temperatures

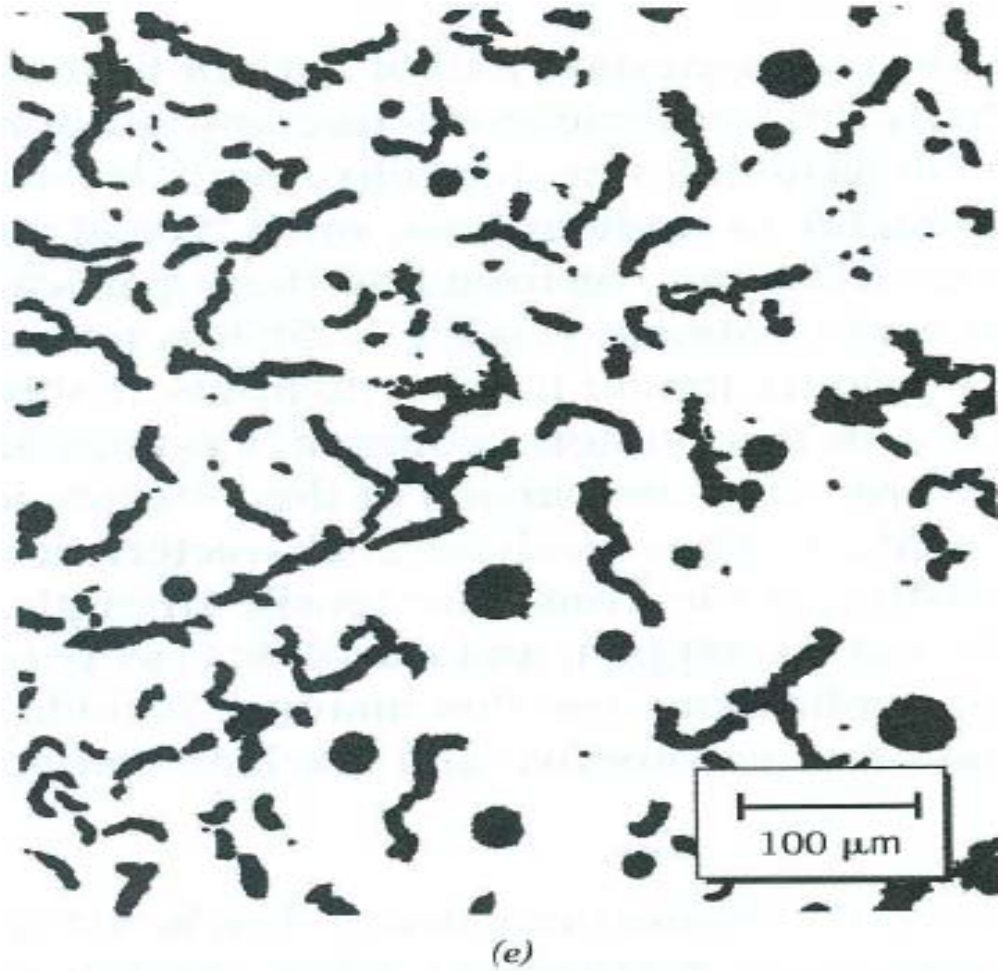
Application:

- Diesel engine blocks
- Exhaust manifolds
- Gearbox housings
- Brake discs for high-speed train
- flywheels



Structural metallic materials

Compacted graphite Irons



Dark graphite wormlike particles Are embedded Within an α - ferrite matrix