Department of Materials Science and Engineering

Cast Irons

Balázs Varbai, PhD, EWE/IWE

Materials Engineering
BMEGEMTBGF1
2022 Fall semester

1

Outline

Properties of cast irons
- Microstructure, C = 2.1 ~ 6.67%
- Mechanical properties
  - 1) Carbon content
  - 2) Cooling rate of the casting
  - 3) Alloying elements

Types
- Gray cast iron
- White cast iron
- Nodular cast irons
- Malleable cast irons

2

2

Carbon content

- Degree of solution

$$T = \frac{C\%}{4.3 - 0.3(Si\% + P\%)}$$

- T>1 Hypereutectic — Ledeburite + Pr. Cementite
- T=1 Eutectic — Ledeburite
- T>1 Hypoeutectic — Ledeburite + Pearlite

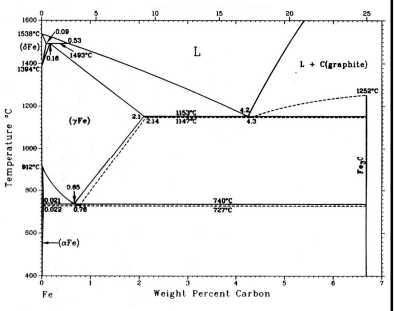
3

3

Cooling rate

- Slow cooling rate
  Iron + Graphite
  section size > 10 mm

- Quick Cooling rate
  Iron + Cementite
  section size < 10 mm



4

4

Alloying elements

- Graphite producing elements
  Co, P, Cu, Ni, Ti, Si, C, Al

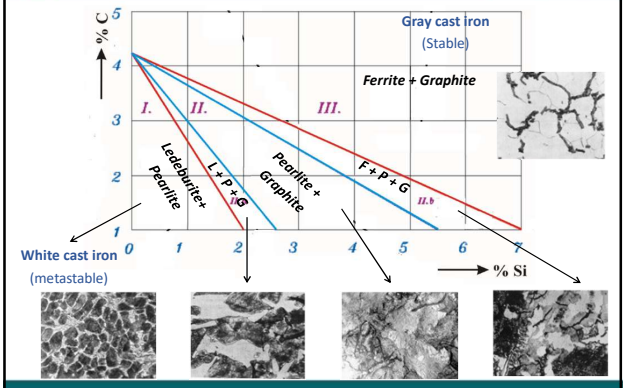
- Carbide producing elements
  W, Mn, Mo, S, Cr, V, Mg, Ce

- The microstructure depends on:
  - Carbon and Silicon content
  - Section size (cooling rate)

5

5

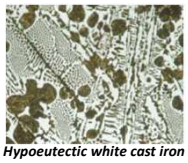
Maurer diagram



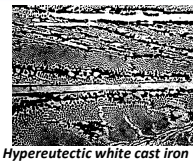
6

6

Microstructure

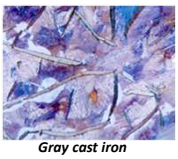


Hypoeutectic white cast iron
Perlite and ledeburite



Hypereutectic white cast iron
Primer cementite and ledeburite

Gray cast iron
Ferrite and graphite

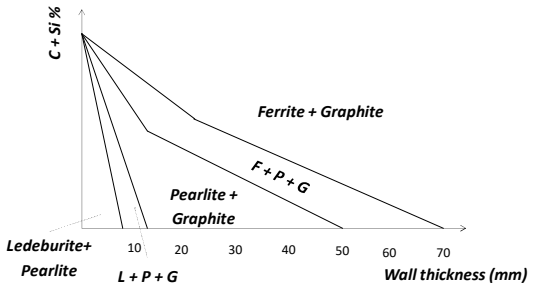


Gray cast iron
Ferrite, perlite and graphite

7

7

Greiner - Klingenstein diagram

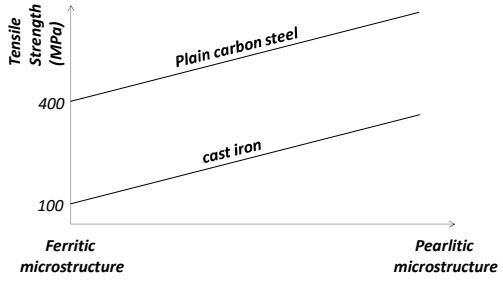


At a given C + Si % the graphite producing elements' effects increases with increasing section size

8

8

Mechanical properties of cast iron



Graphite's effect on tensile strength

- *graphite produces notch effect*
- *graphite excludes parts in the matrix*

9

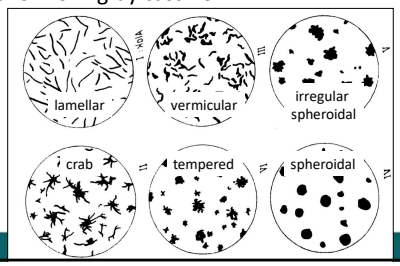
9

Mechanical properties of cast iron

Disadvantage of cast iron

- gray cast iron has low strength
- gray cast iron has no plastic strain = *brittle*

Graphite forms in gray cast iron



10

10

Mechanical properties of cast iron

- Advantage of cast iron
  - good compressive strength
  - high damping capability (tool machines)
  - good machinability
  - good wear resistance (graphite as lubricant)
  - lower cost

11

11

Utilization of gray cast iron

12

12

Increasing the strength of cast iron

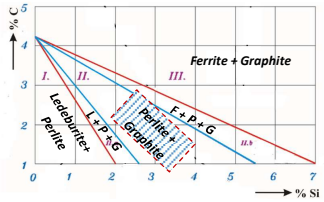
1. Increase the perlite amount in the matrix
2. Modify the shape and distribution of the graphite flakes
3. Alternating the graphite's geometry from flake to spheroidal graphite

13

13

Increasing the strength of cast iron

Increase the perlite amount in the matrix



ASTM A438	**Rm** (ksi)	**Rm** (MPa)	**T**
Class	**20**	150	1
	30	200	0.94
	35	250	0.88

14

14

Increasing the strength of cast iron

Modify the size and distribution of graphite flakes

FeSi and **CaSi** as centers of crystallization (nucleation)

Method: Overheating the molten iron and alloy

FeSi ~0.5% CaSi 0.5~1%

- finer flakes
- higher strength

ASTM A438	**Rm** (ksi)	**Rm** (MPa)	**T**
Class	**40**	300	0.8
	50	350	0.76
	60	400	0.72

15

15

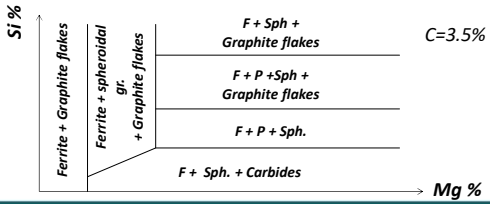
Increasing the strength of cast iron

Alternating the graphite's geometry from flake to spheroidal graphite

Ductile or Nodular cast iron

Mg and Si alloying

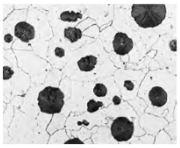
Mg alloying by *Fe-Cu-Mg* and *Fe-Ni-Mg*



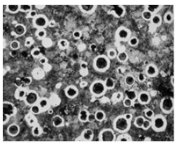
16

16

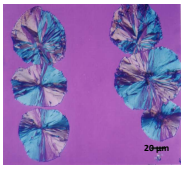
Microstructure



Ductile cast iron
Ferrite and spherical graphite



Ductile cast iron
Ferrite, Perlite and spherical graphite



spherical graphite
in gray cast iron

17

17

Utilization of ductile cast iron

18

18

Ductile or nodular cast irons

ASTM A395	**Rm** (MPa)	**Re** (MPa)	**El** (%)	structure
Grade 60-40-18	400	250	18	Ferrite
Grade 80-55-06	600	370	6	F + P
Grade 100-70-03	700	420	3	P (AQ)
Grade 120-90-02	800	480	2	M (Q+T)

Elongation (%)
Yield Stress (ksi)
Tensile strength (ksi)

19

19

Malleable cast iron

Cast as white CI

Heat treatment

Convert iron-carbibe to temper carbon increases the ductility

White heart malleable CI

Black heart malleable CI

Blackheart malleable iron is made by annealing white iron in a neutral atmosphere, at a temperature of 940° C. Cementite → graphite nodule

Pearlitic malleable CI

Has a matrix, according to the grade specified, of pearlite or other transformation products of austenite.

Whiteheart malleable iron is made by using an oxidizing atmosphere to remove carbon from the surface of white iron castings heated to a temperature of 1000° C.

https://www.britannica.com/technology/iron-processing/The-metal#ref622852

http://www.totalmateria.com/articles/Art96.htm

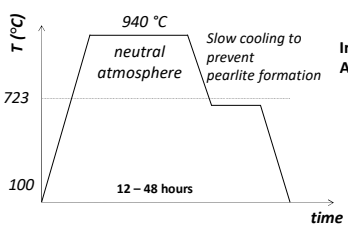
20

20

Black heart malleable cast iron

Ferritic structure with temper carbon

ASTM A47	**Rm** (MPa)	**Re** (MPa)	**El** (%)
Grade 325-10	400	130	10



Ledeburitic - pearlitic structure

Iron carbide dissociates to Fe and C
Austenite transforms to ferrite and graphite

Ferrite + temper carbon

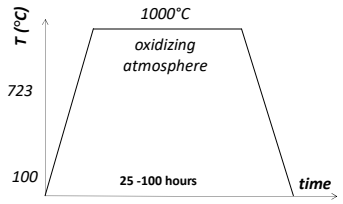
21

21

White heart malleable cast iron

Ferritic structure with low carbon content

ASTM A47	Rm (MPa)	Re (Mpa)	El (%)
Grade 450-06	310	175	6
Grade 600-04	420	250	4
Grade 800-02	550	340	2
Grade 900-01	650	430	1

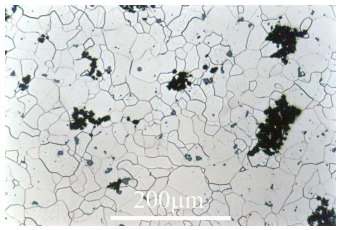


Ledeburitic-perlitic structure
C = ~ 3%
↓
Iron carbide dissociates to Fe and C
↓
Carbon diffuses to the surface and burns there.
↓
Ferritic structure , low carbon
C = ~ 0.1%

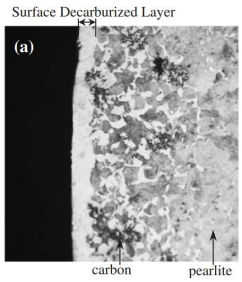
22

22

Microstructure



Black heart cast iron
Temper-carbon in ferrite matrix



White heart cast iron

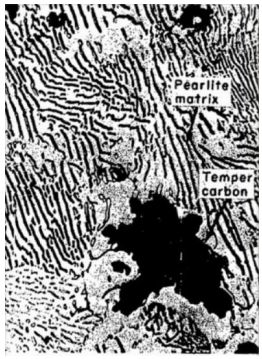
Preparation of White Heart Malleable Cast Iron in Na2O-K2O-SiO2 Oxide Molten Salt Hiroaki Yamamoto, Kenji Shinzaki, Masao Morishita and Koichiro Koyama

23

23

Pearlitic malleable CI

- Higher strenght but lower ductility than ferritic types
- Weldable, but post-weld heat treatment is required
- Heat treatable, 50 – 55 HRC
- Shafts, agricultural machinery, cranks



https://www.slideshare.net/usamatahir66/cast-iron-amp-its-structure

24

24

Utilization of malleable cast iron

25

25

Thank you for your attention!

26

26