Government College of Engineering and Research, Avasari(Khurd)

Department: Mechanical Engineering

Learning Resource Material (LRM)

Name of the course: Engineering Metallurgy **Course Code:** 202048

Name of the faculty: J. M. Arackal **Class:** SE(Mech)

SYLLABUS(Unit 3)

Unit III: Iron-Carbon alloy system & Cast Iron (8 Hrs.) Iron-iron carbide equilibrium diagram, critical temperatures, solidification and microstructure of slowly cooled steels, structure & property relationship, classification and application of steels.

Cast Irons: Classification, Manufacturing, Composition , Properties & applications of white C.I., Grey cast iron, malleable C.I., S.G. cast iron, chilled and alloy cast iron, effect of various parameters on structure and properties of cast irons. Specific applications such as machine tools, automobiles, pumps, valves etc.

Introduction to non-equilibrium cooling of steels, widmanstaten structure

Lecture Plan format:

Name of the course: Engineering Metallurgy **Course Code** 202048

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Unit No	Lecture No.	Topics to be covered	Text/Reference Book/ Web Reference
		Unit 3: Iron-Carbon alloy system & Cast Iron	
3	1	Iron-iron carbide equilibrium diagram, critical temperatures.	1
3	2	Solidification and microstructure of slowly cooled steels, structure & property relationship	1
3	3	Classification and application of steels.	1
3	4	Cast Irons: Classification, Manufacturing, Composition , Properties & applications of white C.I.	1
3	5	Grey cast iron, malleable C.I., S.G. cast iron, chilled and alloy cast iron, effect of various parameters on structure and properties of cast irons .	1
3	6	Specific applications such as machine tools, automobiles, pumps, valves etc.	1
3	7	Introduction to non-equilibrium cooling of steels	1
3	8	Widmanstaten structure	1

List of Text Books /Reference Books/ Web Reference

1- *Material Science & Metallurgy For Engineers", Dr. V.D. Kodgire & S. V. Kodgire , Everest Publication.*

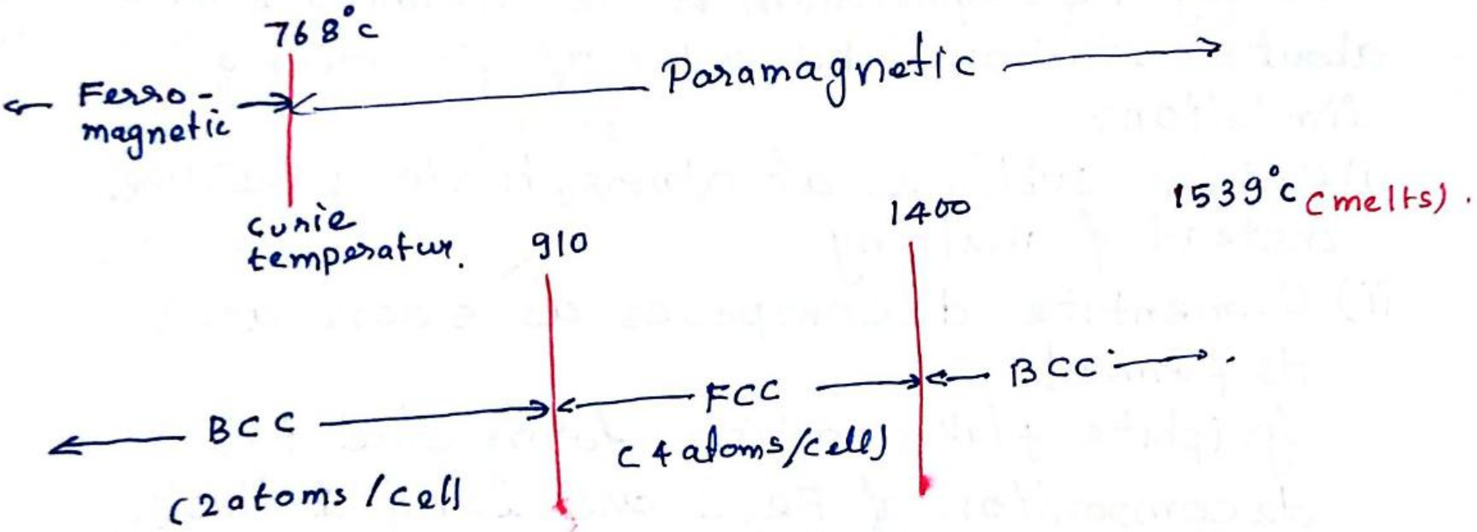
2- *Introduction to Physical Metallurgy, Avner, S.H., Tata McGraw-Hill*

A

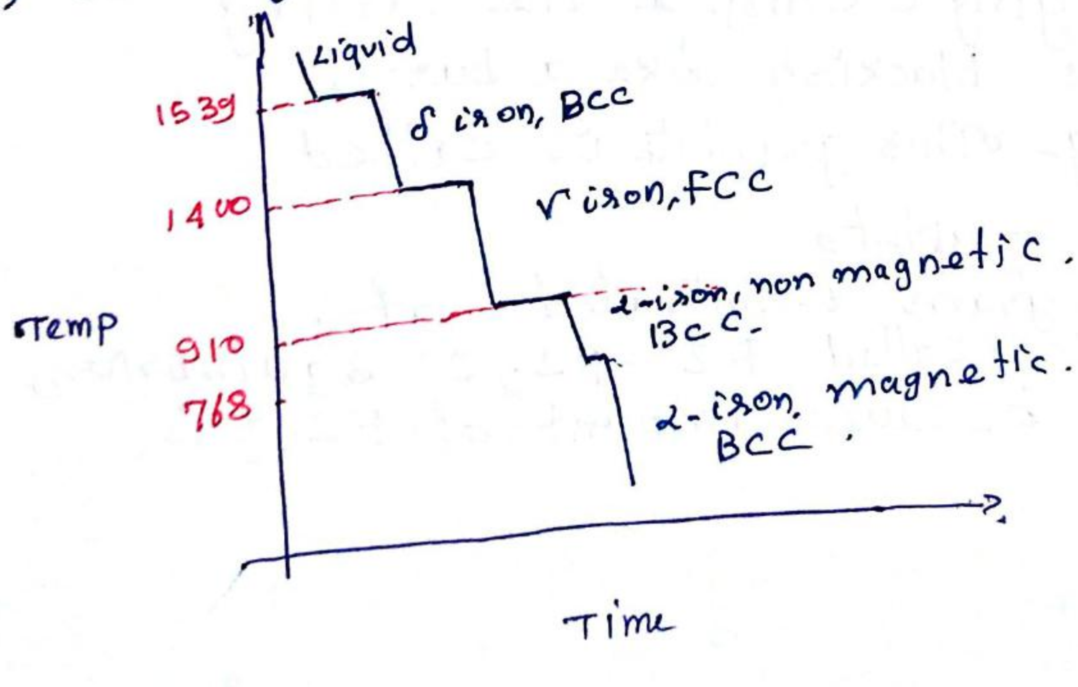
Allotropy, Cooling Curve & Volume changes of Pure Iron.

1) Allotropy of Pure iron:

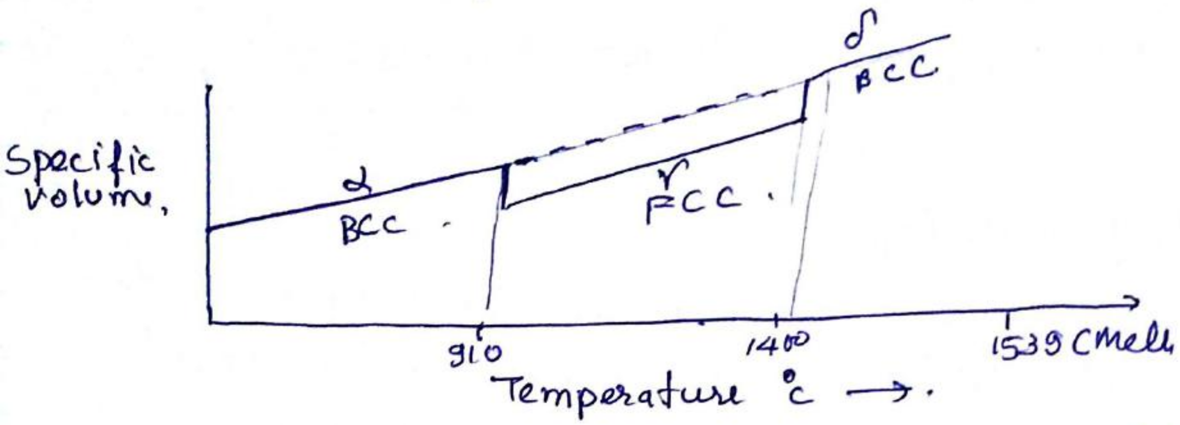
Iron changes its crystal structure from BCC to FCC at 910°c, then again changes to BCC at 1400°c. & with further heating it melts at 1539°c.



ii) Cooling curve of pure iron.



Volume changes of Pure Iron:



The sharp change of volume causes cracks.

Usually Fe-C equilibrium is terminate at about 5% carbon because of following limitations.

i) Carbon sublimes at atmospheric pressure instead of melting.

ii) Cementite decomposes as soon as its formed.

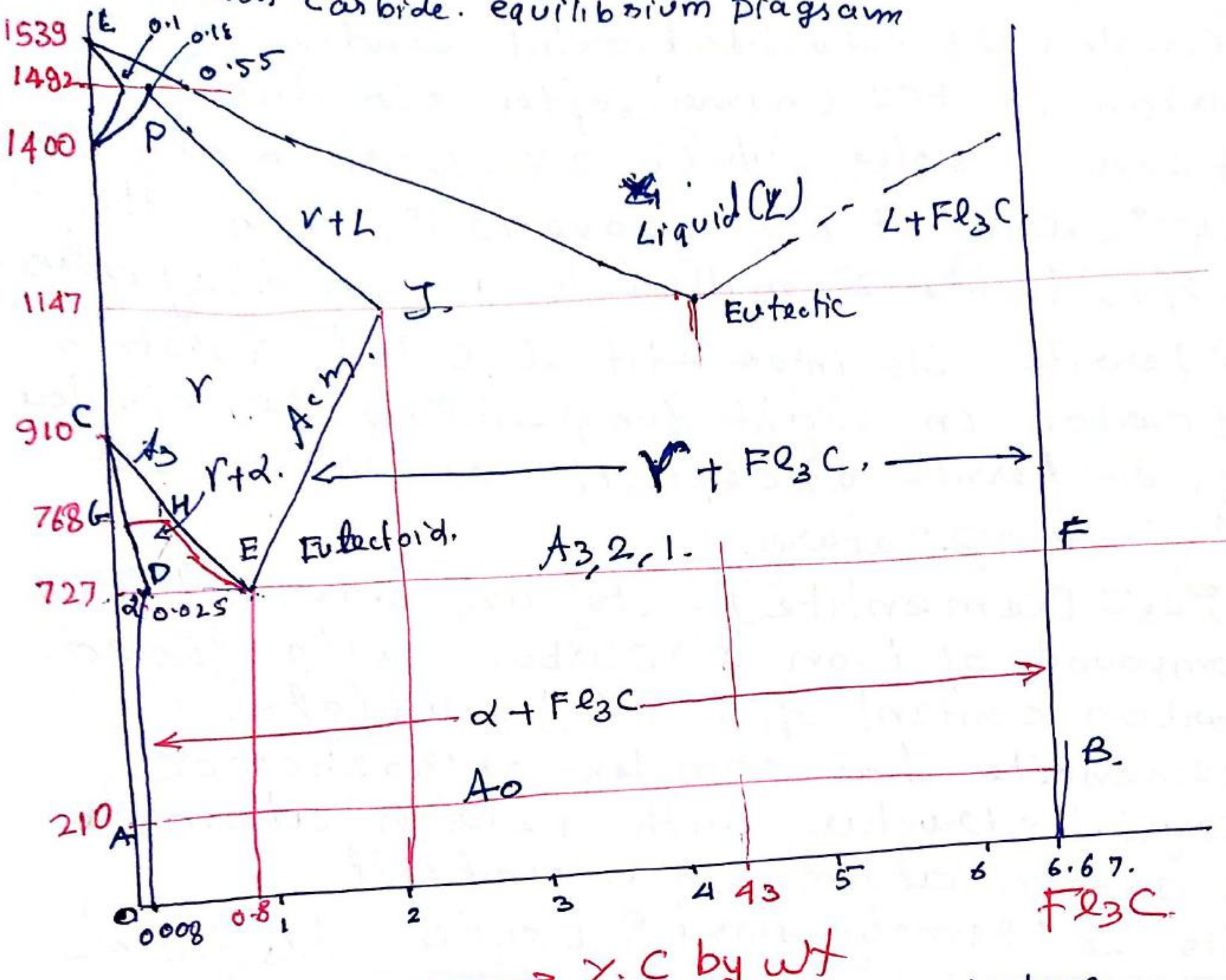
Graphite flakes which form due to decomposition of Fe_3C are long & thick. These flakes float to the surface of solidifying casting & the casting appears blackish like a burnt casting. This graphite is called

kish graphite.

Fe-C diagram terminated at 6.67 C is called Fe - Fe_3C equilibrium diagram because amount of Fe_3C is 100% .

- Steels are alloys of iron - carbon. in which carbon content is between 0.008 to 2%..
- If some amount of other elements are accidently present without any impurities intention, they are called impurities else they are called alloying element.
- sulphur & phosphorous are common impurities, obtained from coke & ore.
- Manganese is always added to steel to minimise effects of sulphur
- Presence of these elements do not affect heat treatment behaviour & microstructure.
- steels with other elements are plain carbon steels.

Iron-Iron Carbide equilibrium Diagram



The various phase that exist are as below.

1) α (Ferrite): Interstitial solid solution of carbon in low temperature BCC [α-iron].

The solubility of α-iron (with carbon) at room temperature is 0.008% & increases with increasing temperature to about 0.025% at 727°C.

Its relatively soft & ductile. phase & can be extensively cold worked without cracking

α is ferromagnetic upto 768°C & becomes paramagnetic at 768°C during heating, this temperature is known as Curie temperature.

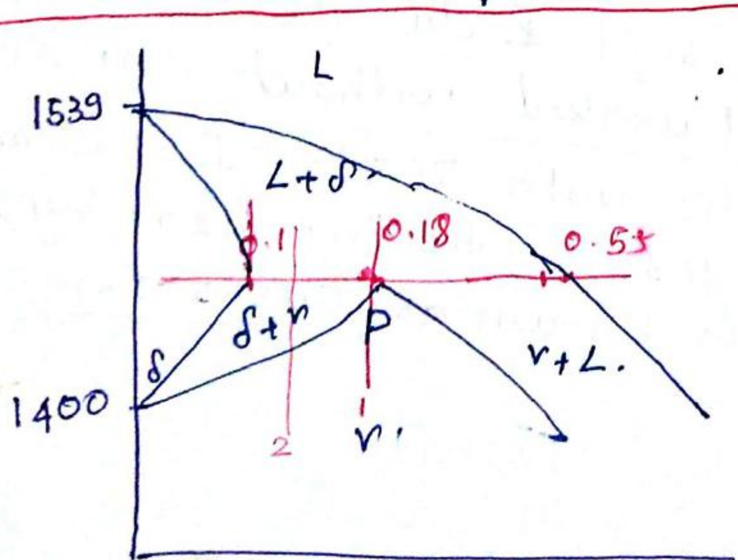
ii) γ (Austenite): Interstitial solid solution of Carbon in FCC (named after sir Austin) It can dissolve up to 2% carbon at 1147°c & its stable above 727°c only. Its soft, ductile & malleable & non magnetic.

iii) δ ferrite Its interstitial solid solution of carbon in hight temperature. Its similar to α-ferrite except its occurance at high temperature.

iv) Fe_3C [Cementite]: Its an intermetallic, compound of iron & carbon with fixed carbon content of 6.67% by weight. cementite has complex orthorhombic crystal structure with 12 iron atoms & 4 carbon atoms in a unit cell. Its extremely hard & brittle Its ferro-magnetic upto 210°c. & paramagnetic above it. Its also Called Iron Carbide or simply Carbide.

Iron - Iron Carbide has following three transformations

i) Peritectic transformation



$S_1 + L \xrightarrow[\text{temp}]{\text{Const}} S_2$, (during cooling

5

Cont Peritectic reaction occurs at the point P.

$$\underset{0.1\%C}{\delta} + \underset{(0.55\%C)}{L} \xrightarrow{1492°c} \underset{(0.18\%C)}{\gamma}$$

Amount of $\delta = \frac{0.55 - 0.18}{0.55 - 0.1} = 82.2\%$.

Amount of liquid $= \frac{0.18 - 0.1}{0.55 - 0.1} \times 100$

$= 17.8\%$.

for hypoperitectic steels.

$L + \delta \xrightarrow{1492°c} \delta + \gamma$

for hyperperitectic steel.

$L + \delta \xrightarrow{1492} \gamma + L$.

For hypoperitectic steels excess of δ &.

for hyperperitectic steels, excess of γ.

All the steels containing carbon 0.1 to 0.55%. C exhibit peritectic transformation

ii) Eutectoid transformation

$$S_1 \xrightarrow[\text{temp}]{\text{Const.}} S_2 + S_3$$

$$\underset{(0.8\%C)}{\gamma} \xrightarrow{727°c} \underset{(0.025\%)}{\alpha} + \underset{(6.67\%C)}{Fe_3C}.$$

The eutectoid mixture of α & Fe_3C is termed as pearlite, due to its pearly appearance. Under optical microscope.

Amount of ferrite (at room temperature) $= \frac{6.67 - 0.8}{6.67 - 0.008}$

$= 88.1\%$.

$\therefore$ amount of cementite $= 11.9\%$.

Critical Temperatures

The temperature at which phase change occurs during heating & cooling.

A_0 → Temperature at which cementite changes from ferromagnetic to paramagnetic.

A_1 : Temperature at which pearlite transforms to Austenite. (Lower Critical temp)

A_2 : Temperature at which ferromagnetic ferrite becomes paramagnetic. Line GH & continues along HEF DEF

A_3 : The temperature at which last trace of free ferrite gets dissolved to form 100% Austenite. (CHE).

$A_{3,2,1}$, for Hypereutectoid, (upper critical temperature)

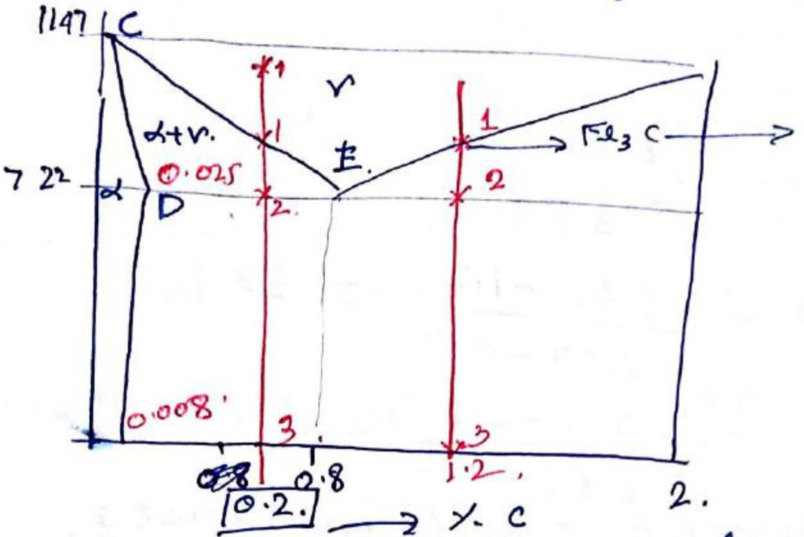
Acm : Last trace of free cementite gets dissolved to 100% Austenite (Line EJ)

Critical points	Temp °C	Significance
A_0 (curie ~~temp of~~ cementite)		
1 A_0 (curie temp of cementite)	210°	cementite becomes paramagnetic.
2 A_1 (Lower critical temperature)	727°	Pearlite starts transforming to Austenite.
3) A_2 (curie temp of ferrite)	768.	Ferrite becomes paramagnetic
4) A_3. (upper critical temperature for Hypoeutectoid steels).	727-910.	completion of ferrite to Austenite.
5) Acm. (upper critical temperature for hypereutectoid steels	727-1147.	completion of cementite to Austenite.
6) A_4.	1400-1492	Austenite to δ ferrite (completion)

During non equilibrium cooling there is a change in critical temperatures due to thermal Hysteresis.
so the above temperatures is denoted by letter 'c' (c from french word chauffage, means heating) & during cooling by letter r (refroidissement, cooling)
eg: A_1 will become Ac_1,
for equilibrium cooling, letter e is used.

Solidification ~~of~~ & Microstructure of slowly cooled steels.

i) Microstructure of hypoeutectoid steels



At 1 – α starts seperating out (proeutectoid α)

Variation of α – along CD & γ along CE

At 2 γ – transforms to Pearlite. by eutectoid transformation

No significant changes from 2 to 3.

$$\text{Amount of } \alpha = \frac{0.8-0.2}{0.8-0.008}$$

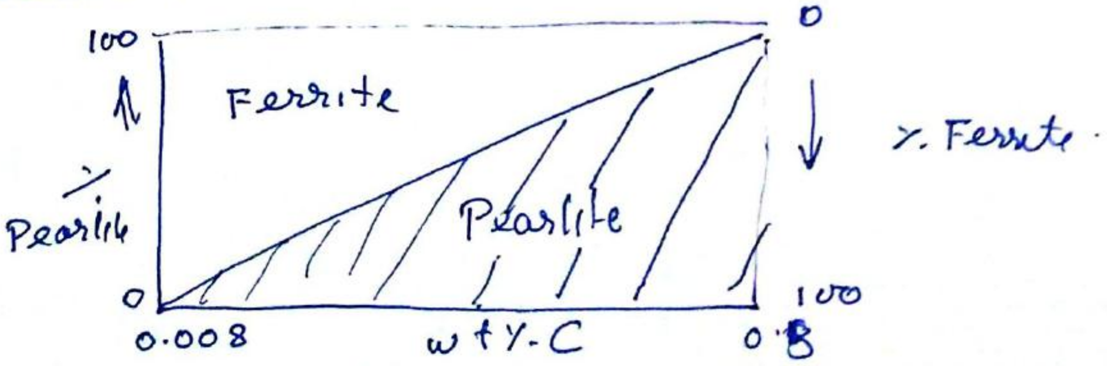
0.008 0.2 0.8

$$\cong 75\%.$$

∴ Amount of Pearlite ≅ 25 %.

Ferrite appears white & pearlite appears dark as lamellas under microscope. with most common reagents – nital & picral.

As carbon increases. proeutectoid ferrite decreases & Pearlite increases.



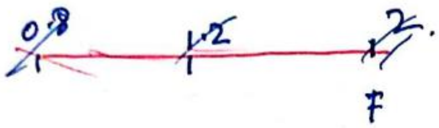
On the basis of microstructure & Appearance.

Microstructures of hypereutectoid steels.

Assuming for 1.2 % of C.

@ 1 → Fe_3C. starts seperating out.

@ 2 → Eutectoid reaction.

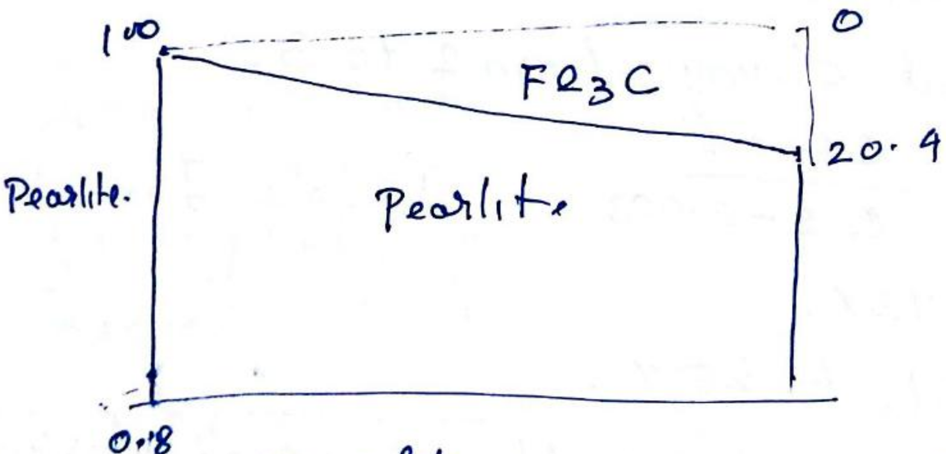


Amount of Pearlite $= \dfrac{6.67 - 1.2}{6.67 - 0.8} = 93.2$

Amount of Fe_3C $= \dfrac{1.2 - 0.8}{6.67 - 0.8} = 6.8\%$

As % of C increases. Fe_3C will increase till 2 % of C.

∴ Amount of Fe_3C in steel, $= \dfrac{2 - 0.8}{6.67 - 0.8} = 20.4\%$



Pearlite appear dark or lamellas

Cementite appears white

Property variation with Microstructure.

Average property (for α – β alloy) = (Amount of α × The property of α) + (Amount of β × The property of β).

i) For Hypoeutectoid steels

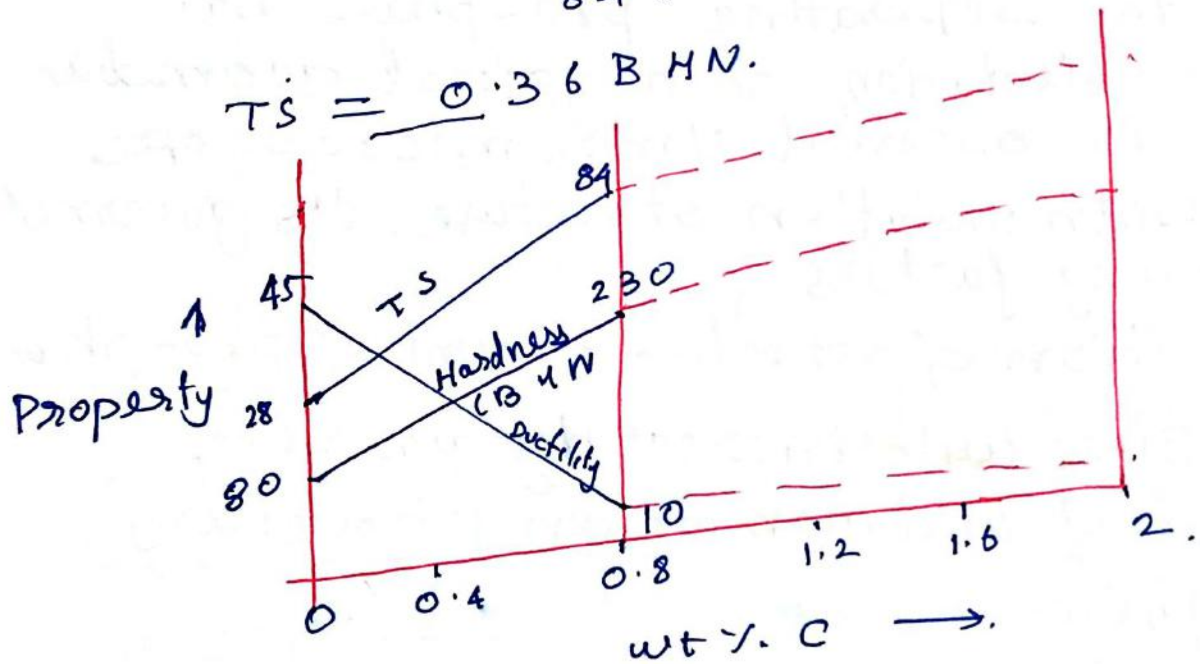
BHN = 80 × Amount of α + 230 × Amount of pearlite.

ii) for Hypereutectoid steels

VPN = 900 × Amount of Fe_3C + 240 × Amount of Pearlite.

iii) TS (kg/mm^2) = 28 × Amount of α + 84 × Amount of Pearlite.

TS = 0.36 BHN.



Widmanstatten structure:

During cooling of steel from Austenitic region, sometimes proeutectoid phase seperates not only along grain boundaries, but also in grains along certain crystallograph planes & directions.

During any transformation, the system tries to reduce energy to its maximum level, so phase seperations can occur at interphase having very similar atomic spacing.

So the seperating pro-phase has definite orientation, so a typical geometric pattern is observed under microscope called widmanstatten structure. Its governed by following factors.

i) composition of steel. → Amount of pro-pha

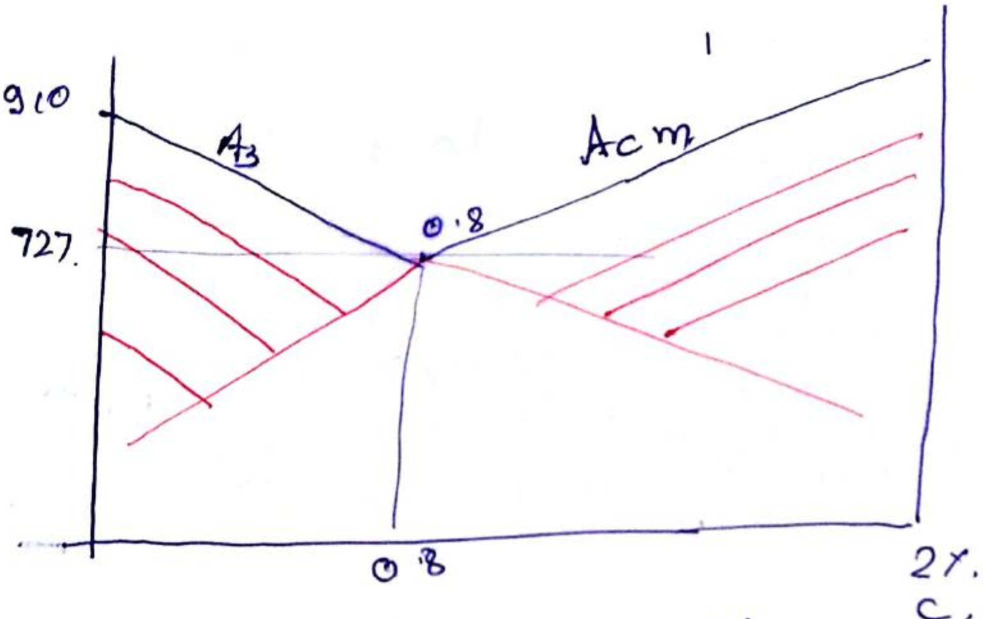
ii) Grain size: with increased grain size, chances of widmanstatten structures are higher.

iii) Cooling rate:

faster rate – proeutectoid will not migrate to grain boundaries & so it gets precipitate inside grain boundaries showing widmanstatten structures.

Non equilibrium cooling of steels

Faster the cooling, lesser will be the eutectoid transformation temperature shift of eutectoid carbon to lower values for hypoeutectoid steel & higher value for hypereutectoid steels.



The amount of pearlite can be controlled by controlling the cooling rate. There is a certain limit, if the cooling rate exceeds a certain value called as critical cooling rate, Austenite does not transform to pearlite but transforms to a phase called Martensite.

If Austenite is cooled isothermally at some temperature below the lower critical temperature Bainite is obtained.

Cast Irons.

Carbon varies between 2 to 6.67.

CI have following characteristics in comparision to steel.

i) Cheap alloys.
ii) Easier to melt (1150-1250°c).
iii) Excellent castability.
iv) fairly good corrosion resistance.
v). Properties can be adjusted. over a wide. & useful range. by alloying / Heat treatment.

But in general they are brittle &. their mechanical properties are inferior to steels.

classification of CI.

on basis of furnace used in manufacture
- Cupola CI
- Air furnace CI.
- Electric furnace CI
- Duplex CI (Melted in one & refined in the other)

on basis of composition & purity
- Low carbon, low silicon CI
- High carbon, low sulphur CI
- Nickel & Alloy CI

On the basis of microstructure & Appearance of fracture.

1) White Cast Iron:
All carbon in the combined form & the fracture is white.

2) Malleable Cast Iron: They contain free carbo[n] i.e. graphite, in the form of irregular spheroids called as temper carbon-graphite nodules (rosetts). They are formed from white CI by malleablizing (Heat Treatm[ent]

3) Gray Cast Iron: free carbon in the form of flakes; fracture is gray.

4) Nodular CI: Graphite (free carbon) in the form of nodules or spheroids. Its produced from gray CI, by addition of small amou[nt] of magnesium just prior to pouring

5) Mottled CI: It has microstructure of both gray CI & white CI

6) Chilled CI: They show white CI on the surface & gray CI at the centre.

7) Alloy CI: Alloying elements to the above

Decomposition of cementite → graphite

Factors affecting / Influencing Microstructure. 2

Amount of total Carbon:
Carbon is graphitizer: with increasing Carbon, the tendency of graphitization (formation of graphite by decomposition of Cementite.) increases.

$Fe_3C \rightarrow 3Fe + C$. [gray CI].

· with higher Carbon & slower cooling, the matrix may become ferrite.
At moderate cooling rate & less amount of Carbon, the CI may solidify as white CI (ie without graphitization).

ii) Amount of Silicon:
silicon is a strong graphitizes
Amount of Silicon varies from 0.5 to 3%.

$$\text{Si equivalent} = \%Si + 3(\%C) + \%P + 0.3(\%Ni) + 0.5(\%Al) + 0.3(\%Cu) + 0.5(\%Al) - 0.35(\%Mo) - 1.2(\%Cr) - 0.25(\%Mn)$$

↓
limit graphitization.

iii) Amount of phosphorous: strong graphitizer (0.1 to 0.3 %). Most of phosphorous combined with Iron & forms Iron phosphide (Fe_3P); which seperates out as eutectic mixture with Cementite & austenite; this mixture is also called steadite.
It has freezin point of 980°c.

steadite, is brittle (It may merge to form a continous network around primary dendrites of Austenite.

However, phosphorous increases fluidity of CI.

Equivalent Carbon = Total Carbon + $\frac{1}{3}$ (Si + P).

Equivalent carbon may be used for predicting amount of graphitization

Amount of Sulphur.

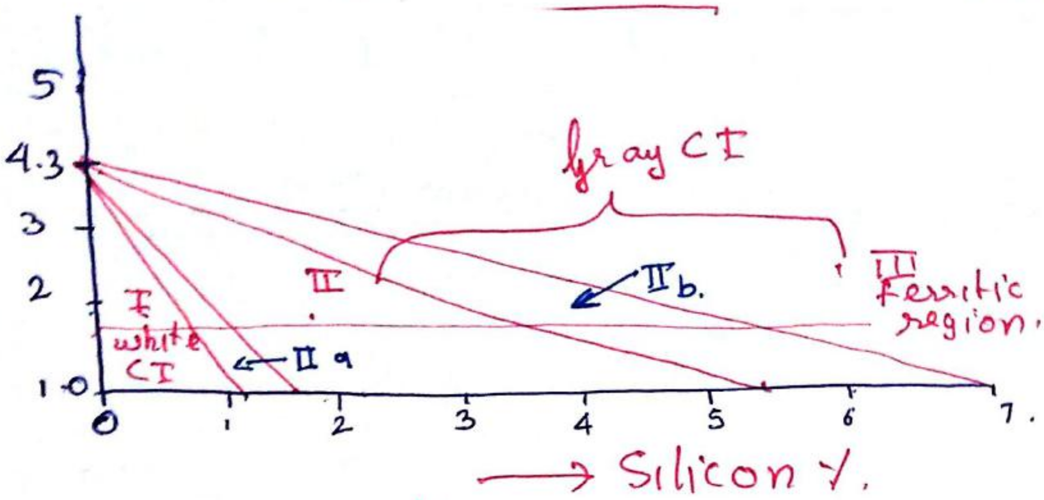
Sulphur combines with Iron & forms iron sulphide (FeS) which is hard & brittle compound. Sulphur has a greater affinity for manganese than for iron & form MnS, Manganese sulphide, which does not affect CI. FeS also promotes formation of iron carbide, Range: 0.06 to 1.2 %.

) Amount of Manganese: It reduces the brittleness likely to be introduced due to formation of iron sulphide. Range: 0.5 to 1 %.

) cooling Rate:

Rapid cooling supresses graphitisation, resulting in white CI.

Slow cooling favours graphitization of Fe_3C & may result in gray CI



Region I - white CI

Region II - Pearlitic C I.
sufficient silicon to cause graphitization of all cementite except of Eutectoid cementite (cementite in the pearlite).

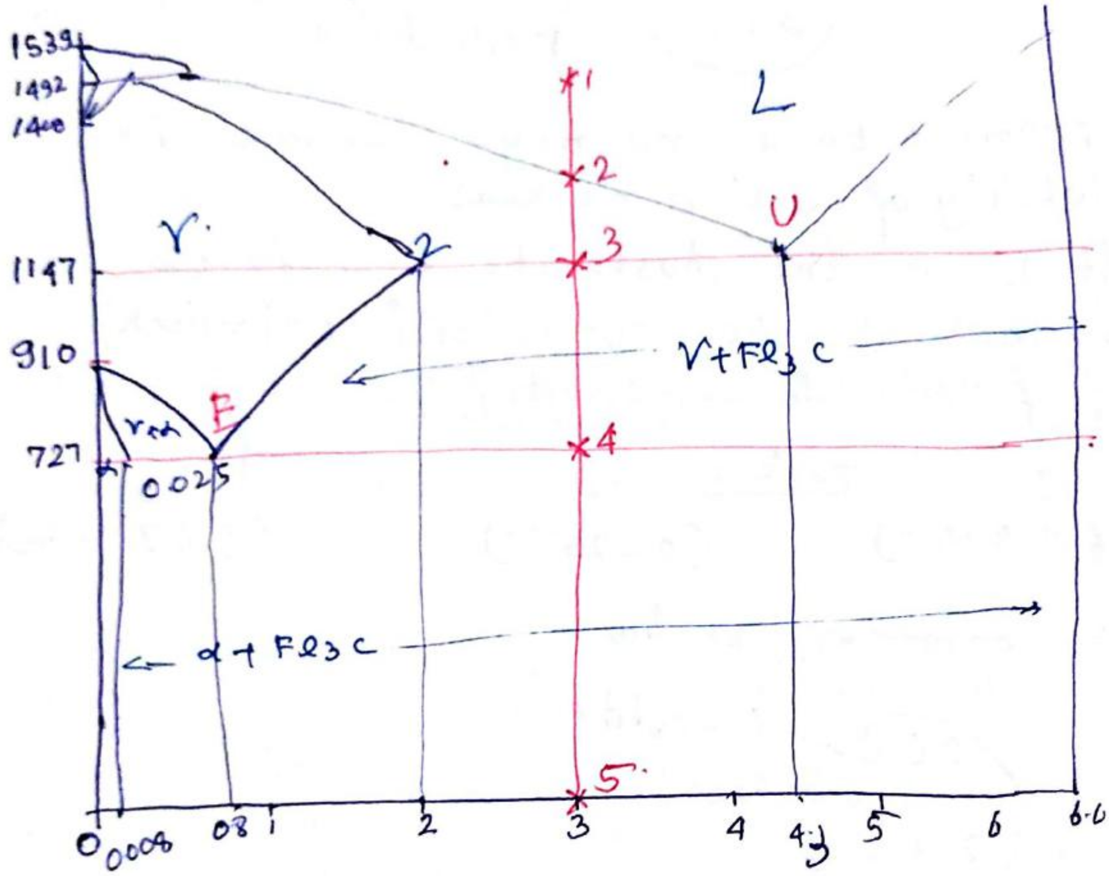
IIa → Mottled C I.

IIb → Pearlitic - ferritic.

White CI

Carbon is present in the form of combined. Carbon (cementite) & there is no free carbon, solidification of white CI & the resulting microstructure is as per Fe - Fe_3C.

A) Cooling of hypoeutectic CI with 3% Carbon



@1 → Liquid state.

@ just below 2 – till 3. γ starts separation, proeutectic γ (dendrites).

@3 applying Lever Rule.

Amount of Austenite (2% carbon @1147° C). = $\frac{4.3 - 3}{4.3 - 2}$ = 56.52%.

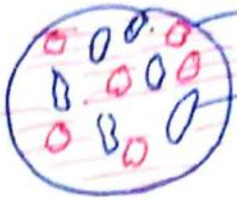
Remaining 43.5%. alloy exist in Liquid State with 4.3% C.

The liquid undergoes eutectic reaction

$$\underset{(4.3\%C)}{\text{Liquid}} \xrightarrow{1147^\circ C} \underset{(2\%C)}{\gamma} + \underset{(6.67\%C)}{Fe_3C}$$

ledeburite.

From 3

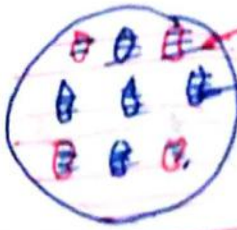


From 3 to 4 no major change, but solubility of Carbon decreases.

At 4. all the Austenite transforms isothermally to eutectoid mixture of ferrite & cementite [Pearlite].

$$\underset{(\text{of } 0.8\%C)}{\gamma} \xrightarrow{727^\circ C} \underset{(0.025\%C)}{\alpha} + \underset{(6.67\%C)}{Fe_3C}$$

~~At room temperature.~~



At room temp → Pearlite is in a matrix of Cementite.

B: Cooling of Eutectic CI
No proeutectic Austenite.

C: cooling of Hypereutectic CI
proeutectic cementite will be formed.

Due to presence of Carbon in combined form, white CI contains large amount of cementite. & hence they are hard & brittle.

∴ Majority of white CI are hypoeutectic in Carbon with following composition range.

C – 2.3 to 3 %.

Si – 0.5 to 1.3 %.

S – 0.06 to 0.1 %.

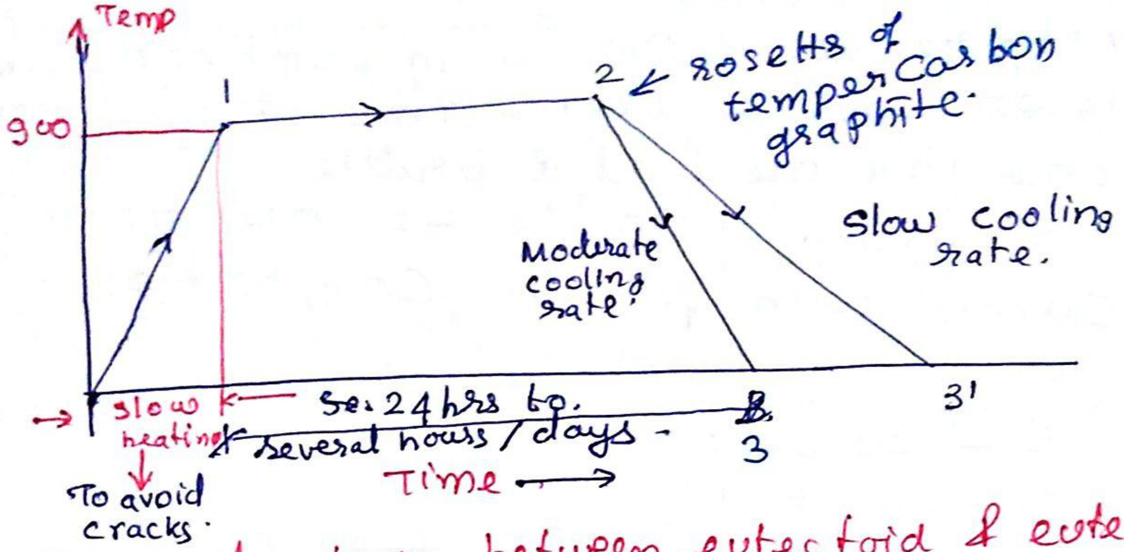
P – 0.1 to 0.2 %.

Mn – 0.5 to 1 %.

- white CI are hard. – 350 to 500 BHN.
- Difficult to machine & therefor, their finishing to final size is done by grinding.
- Applications. wearing plates, road roller surface, pump liners, mill liners, grinding balls, dies & extrusion nozzles. They are not used for structural parts because of their excessive brittleness.

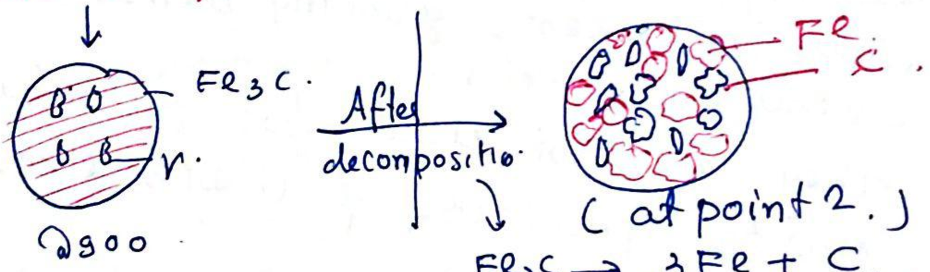
Malleable CI :

These CI are produced from white CI. by malleablizing heat treatment.



900 → Any temp between eutectoid & eutectic.

At 900°c, structure of CI consist of Austenite & Cementite, Cementite is metastable so. Cementite decomposes to Austenite & graphite with a long holding time, resulting to a rough, ragged irregular, irregular nodules or spheroids called as rosetts of temper graphite ~~in a m~~ in a matrix of Austenite.



$Fe_3C \rightarrow \underbrace{3Fe}_{Austenite} + \underbrace{C}_{rosetts}$

Cooling to a room temp with moderate cooling rate transforms Austenite to pearlite.

∴ @ 3 ⟶ Rosetts of carbon graphite + Pearlite (Matrix)

But if cooling rate is low/slow, cementite from pearlite may decompose giving ferrite & graphite at room temperature.

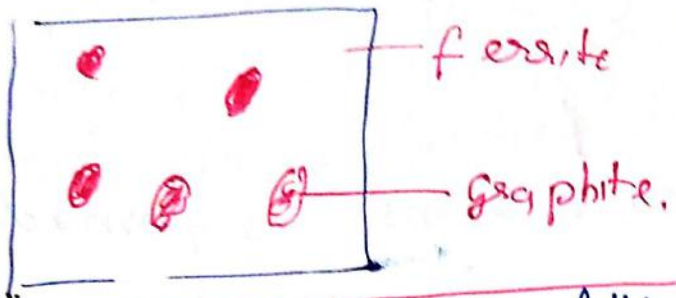
∴ @ 3' ⟶ Rosetts of carbon graphite + Ferrite (Matrix).

for intermediate conditions, matrix may be pearlite & ferrite.

These rosettes disrupt the steel like matrix much less as compared to flakes of gray CI & so diminish internal notch effects.

Types of Malleable Cast Iron:

i) Ferritic malleable:
formed due to slow cooling from malleablizing temperature to room temperature.



It has sufficient plasticity & toughness.

Its used for pipe fitting, valves, farm equipment, chains, bearing block & automotive parts that requires ductility & toughness.

ii) Pearlitic Malleable: Moderate cooling rate. Proeutectoid cementite gets graphitized but eutectoid cementite does not get graphitized.

Used for electrical application like switch gear, fittings for high & low voltage transmission & distribution systems, & for railway electrification

iii) Pearlitic - Ferritic Malleable: Intermediate cooling rate & even properties.

iv) Black heart malleable: Dark grey appearance in the central region or core, due to decarburization at the surface, the ferrite region has no temper carbon. Its simply a ferritic malleable CI

v) white heart malleable:

CI completely free from temper carbon. graphite.

Gray Cast Iron.

Graphite in the form of flakes

Graphite in these cast irons is formed. during freezing.

Graphite flakes interrupt the steel like matrix & hence they are brittle -

They are the cheapest of all ferrous alloys & easiest to cast.

They have excellent damping capacity due to more internal discontinuities. which favours. fast dissipation of vibrational energy.

They have following useful properties.

- Excellent machinability
- Good compressive strength
- Good bearing properties.
- Good corrosion resistance.

They suffer from. the following defects.

Growth. permanent expansion when heated above 400°C.

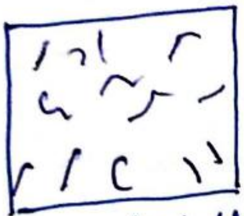
Fire Cracks/Heat Checks: occurs due to. repeated local heating & cooling of the. order of 550°C:

The drawbacks are reduced by use of Silicon & controlling the cooling rate

Properties	TS — 15 to 40 kg/mm^2 Hardness — 150 to 300 BHN. Elongation — less than 1 %.
Applications: Machine bases, engine frames, drainage pipes, elevators & Industrial furnace counter weights, pump housing, cylinders & pistons of IC engines, flywheel etc.	

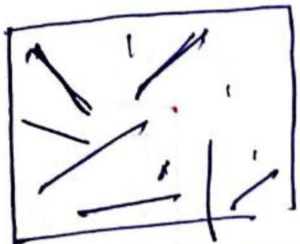
Types of gray CI:

Depending on distribution of graphite flakes. AFA (American foundrymens Association & ASTM. have classified in five types.



Type A: uniform distribution, & random orientation.

Type B: Rosette grouping, random orientation.



Type C: Super-imposed flakes of various sizes random orient[ation]

Type D.: Interdendritic flakes, random orientation

Type E: Interdendritic fla[kes] preferred orientation.

Meehanite (High duty Cast Iron):

Its a grade of gray Cast Iron in which additions of calcium silicide are made to the melt to produce a fine & uniform size distribution of graphite flakes to obtain excellent mechanical properties ($\frac{1}{4}$ inch to $\frac{1}{8}$ inch, in 100x),

Its also called inoculated gray CI. Inoculants (ferro silicon with 75% Si, calcium silicide, etc) are added to liquid CI in the ladle before pouring into the moulds.

The structure obtained after solidification is gray with fine & random distribution of graphite flakes, this gives high strength & hence this CI is called as "High duty CI".

TS — 25 to 40 kg/mm².
used for machine parts subjected to wear, such as gears, brake drum, steam engine cylinders etc.

Nodular Cast Iron.

Graphite is in the form of nodules or spheroids, due to this, the interruption in the steel like matrix is less as compared to the Interruption produced by flake graphite of gray Cast Irons.

Magnesium, cerium, calcium, barium, lithium & Zirconium are the commonly used nodulizing elements.

The addition of Mg (0.06 to 0.08 %) is done to the gray cast iron melt usually in the ladle just prior to pouring into the moulds.

The effect of nodulizing CI elements is purely temporary & is lost due to long holding time. Remelting of nodular CI produces gray CI, unless fresh nodulizing addition is done.

Mg is chemically reactive & has low density. If they are added in pure form they float to the top of bath & burn or decompose at the surface. So they are usually added in the form of master alloys. They have a strong affinity to sulphur, so the amount of sulphur should be less, this is done by treating the melt with soda ash (sodium carbonate). The addition also creates large amount of gases, which can cause blow holes.

They have high Tensile strength, ductility & toughness. They combine the advantage of CI & steels & do not have defects of growth & fire cracks.

Its postulated that addition of nodulizing elements may be affecting surface tension favouring nodule formation

T.S – 38 to 50 kg/mm²
Elongation – 6 to 20%.
Hardness – 100 to 300 BHN.

Used for crankshaft, gears, punch dies, sheet metal dies, metal working rolls, furnace doors, pipes, pistons, cylinder blocks & heads, and bearing blocks.

Mottled Cast Irons:

These CI shows free cementite as well as graphite flakes in their microstructure.

Its observed for intermediate cooling rates.

Mottled structures donot have good properties & should be avoided. This can be done by adjusting silicon content.

Chilled Cast Irons

They show white structure (white CI) at surface & gray structure in the centre. So outer surface has hardness & wear resistance & inner is having damping capacity & good machinability.

Rapid cooling gives white structure & usual cooling gives gray structure.
[C – 3.3 to 3.5 & Si – 2 to 2.5 %]

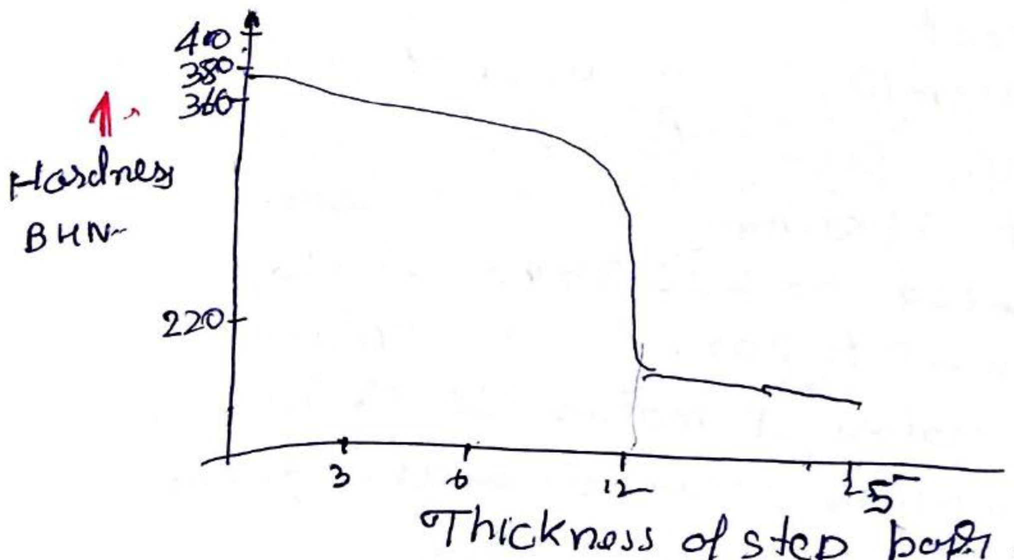
Depth of chill can be adjusted by controlling cooling conditions or by adjusting silicon content.

Chilled CI are used for railway freight car wheels, crushing rolls, grinding balls, road roller, hammer dies.

Chill Test: used to obtain the idea of the depth of chill in chilled castings.

A test sample of melt from cupola or ladle is poured in a sand mould in the shape of wedge or stepped shaft (to give variable cooling rate).

Test sample is fractured & the chill depth, ie the zone which appears white is estimated by observation.



Alloy Cast Irons:

1) ~~Ni-hard~~:

CI have low impact resistance, corrosion resistance & temperature resistance, all these properties are improved by alloying.

Ni, Cr, Mo, V, Cu & Sr are the commonly used alloys.

i) Ni-hard: Hardness & wear resistance is improved by addition of nickel & chromium, with improvement in toughness.

Because of more carbon & alloying elements in Austenite, M_f is below room temperature. So martensite transformation does not complete in room temperature.

But nickel is a graphitizer (half powerful) a silicon, so chromium is added which is a carbide former.

So Ni – 3 to 5 %.

Cr – 1 to 3 %.

BHN – 550 to 700 BHS against 350 to 500.

Ni-har hard has lesser impact strength.

ii) Ni-Resist:

14 – 36 %. Nickel.

1 – 5 %. Chromium.

Some contain Cu – 5 to 8 %.

TS – 15 to 36 kg/mm².

Hardness – 100 to 250 BHN

elongation – 5 to 20 %.

used in generators & motor covers, pump bodies, impellers; valve seatings, exhaust manifolds, furnace parts, sewage pipes & cylinder liners.

iii) Silal & Nicrosilal:

Silicon 5 to 7 %. is added to low carbon CI to increase oxidation resistance & to prevent growth of CI at elevated temperatures.

But Silal is highly brittle.

Addition of nickel & chromium reduces brittleness. (Nicrosilal).

Microsilal. used for exhaust manifold, gas turbine components, aluminium melting crucibles glass moulds, retorts. 10

Heat Treatment of Cast Irons.

i) Stress Relieving:

Heating 400-500°c. releives the internal stresses developed due to uneven cooling. This is called seasoning of castings.

ii) Annealing:

Done @ 800° to 900°C. Malleablizing heat treatment of white CI is annealing

iii) Hardening & tempering.

The heat treatment consists of heating Pearlite to just above upper critical temperature. & cooling rapidly to room temperature, usually in oil.

iv) Surface hardening:

flame hardening or induction hardening or even nitrided to increase hardness, wear resistance & abrasion resistance.