Ni_3Al = Superalloys (perfectly ordered)

$H = E + PV$

$G = H - TS$

Heat Treatment: Technology.

1) Introduction:-

2. Fe - Fe_3C phase diagram Lim.

3 TTT diagra, Limitati.

4. CCT diagram

5. Mechanism of pearlite → Austenite Transfer

Kinetic of

6. Mechanism of Austenite → ~~Banite~~ Pearlite

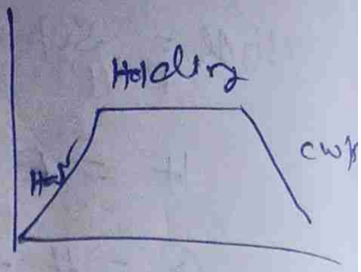
Kinetic

7. Austenite → Banite

Austenite → Martensite

Structure property relationship.

Purpose of Heat Treatment:



(i) To relase internal stress.

2. To improve magnetic property.

3. To .. Thermal :

4. To increase ductility, Toughness, tensile strength

5. To refine grain size.

6. To increase hardness.

Heat Treatment variable

-1> Heating rate :- size & shape of specimen

small size → can be fast

Large size :- should be slow.

Shape - Normal.

complex (variable thickness section, sharp bends,

Holding temp :-

by chemical composition of steel

(%C)

→ If complex carbide are present.

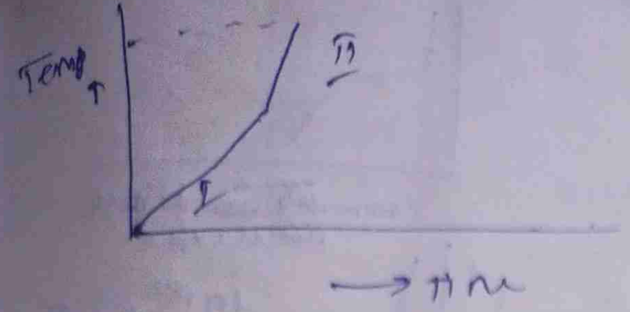
→ other than Fe_3C

holding temp should be higher

→ (iii) Holding Time :- size of specimen.

small size → less time

Large → Large time.

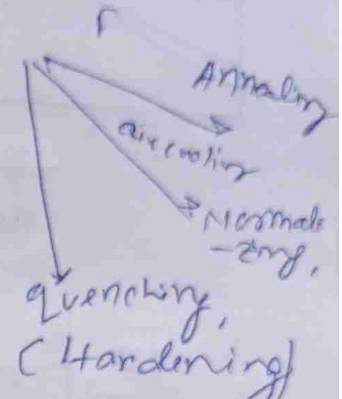


(iv) cooling rate:

1. very slowly.

ii. reatively fast.

(iii) Fast quenching.



TTT diagram:-

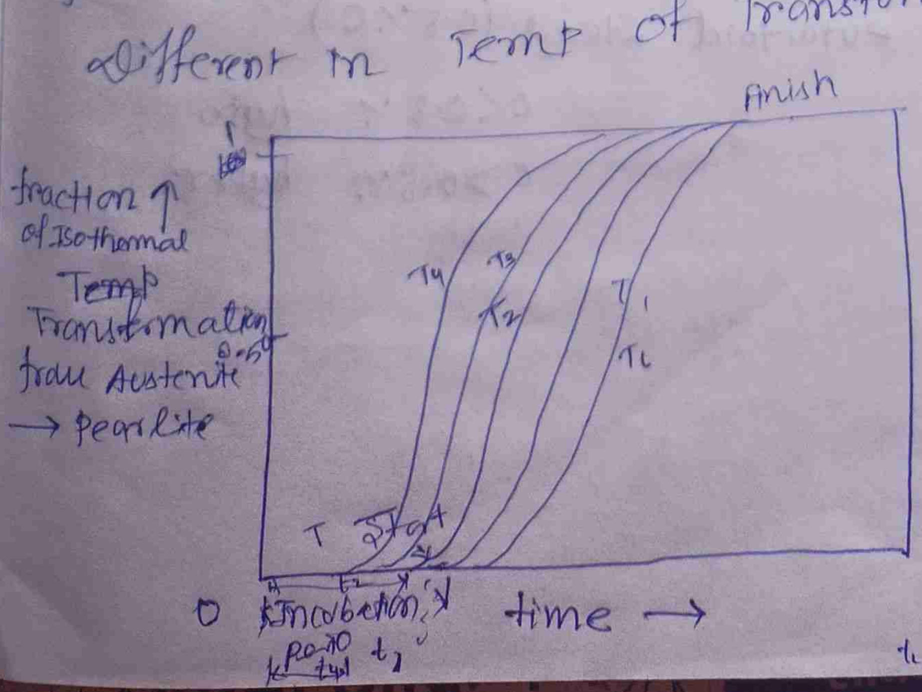
Large No samples (same composition) each samples is heated to austenite range holding to specific variable depending upon size of samples. than quickly cooled followed by holding at different temp below A_1 till the transformation from Austenite to Pearlite is complete.

Different in Temp of Transformation → very small.

$T_3 < T_2$

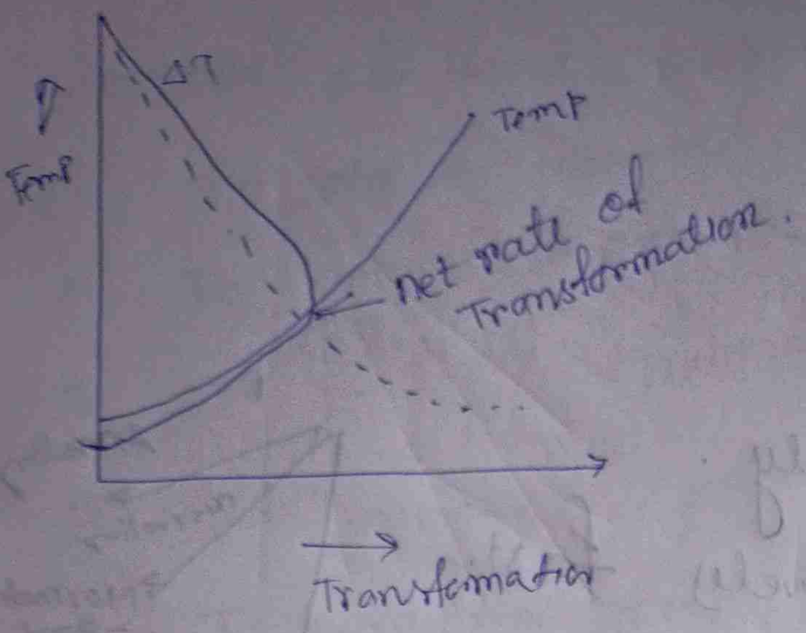
$T_4 < T_3$

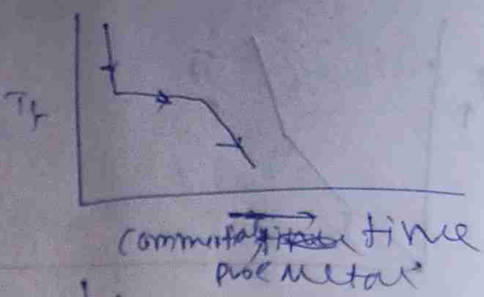
$T_6 < T_5$ → Incubation period ↑

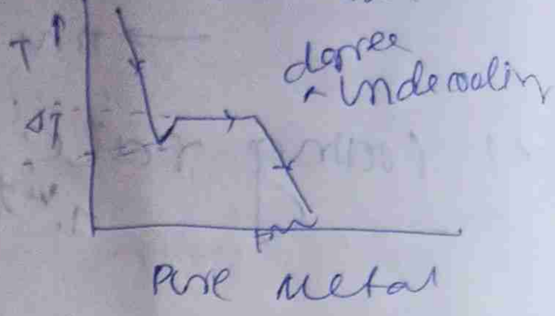


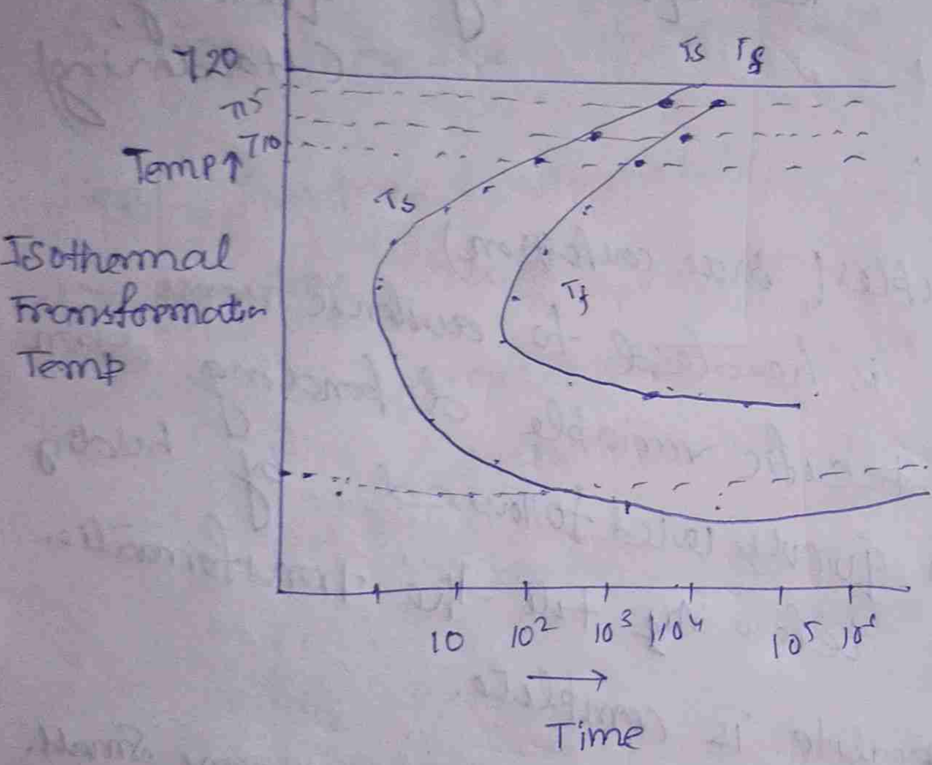
$T_2 < T_1$

$t_2 < t_1$







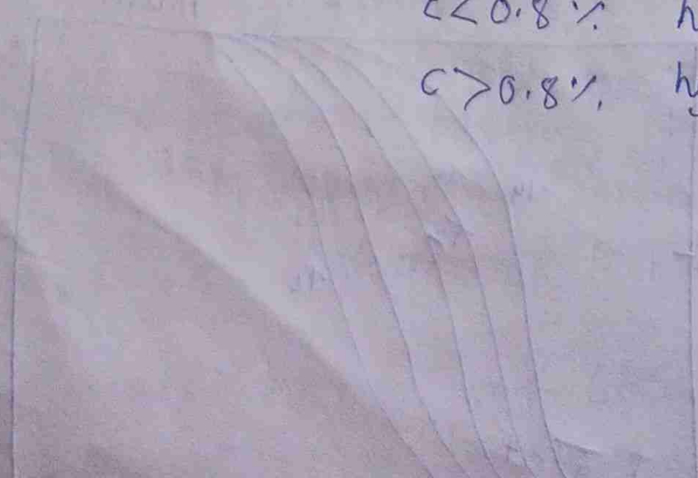


eutactoid Steel (0.8% C)

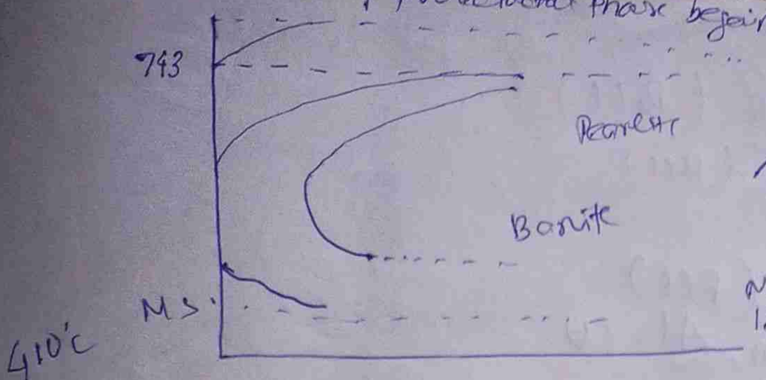
C<0.8% hypo

C>0.8% hyper

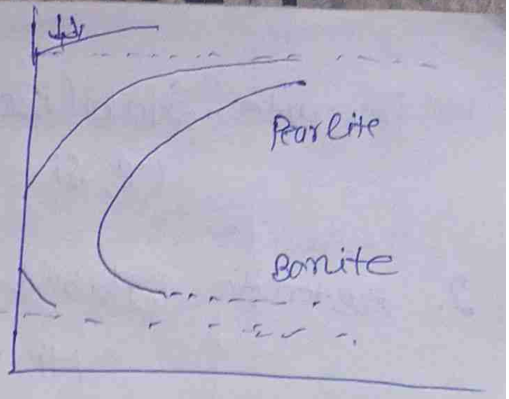
0.35% C
1.14% C



Formation of proeutectoid phase begin

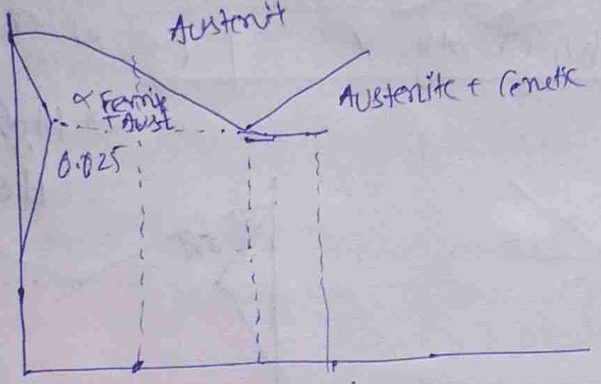


0.35% C →



1.1 % C

Formation proeutectoid (↓↓) cementite.



0.025 ~~0.008~~ 0.35 0.8

proeutectoid ferrite   Pearlite

0.8 1.11 6.67

Pearlite   proeutectoid cementite

$$f_\alpha = \frac{0.8 - 0.35}{0.8 - 0.025}$$

$= 0.6$

$= 60\%$

$$f_{\text{cementite}} = \frac{1.11 - 0.8}{6.67 - 0.8}$$

$= 0.0528$

$= 5\%$

If % C is low Ms ↑

As % C is increase Ms ↓

Effect of Alloying element in Fe - Fe_3C phase diagram.

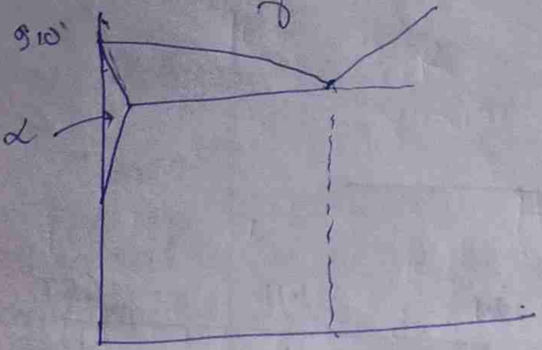
C
Si
Mn
P
S

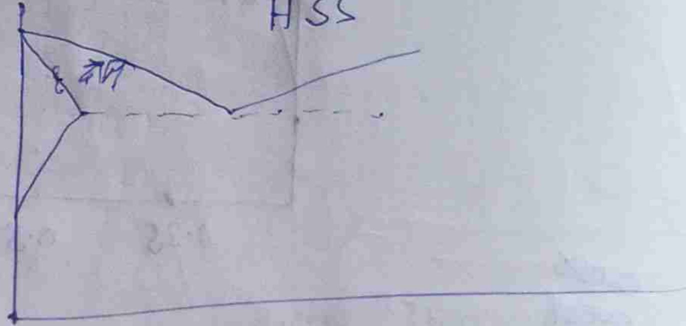
Alloying element + those knowingly added.

(1) Ferrite Stabilizers (BCC)
Cr, Si (BCC)

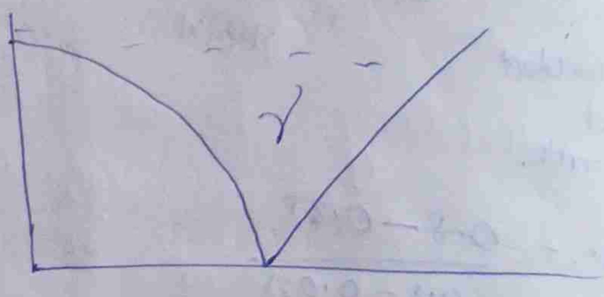
2. Austenite stabiler (FCC)
Ni, Mn, Al, Cu

(iii) Carbide formers
Co, W, Cr, Mo, V [Fe, W, Cr, Mo, V]$_x$C
→ High carbon steel,
HSS





with addition Ni. →



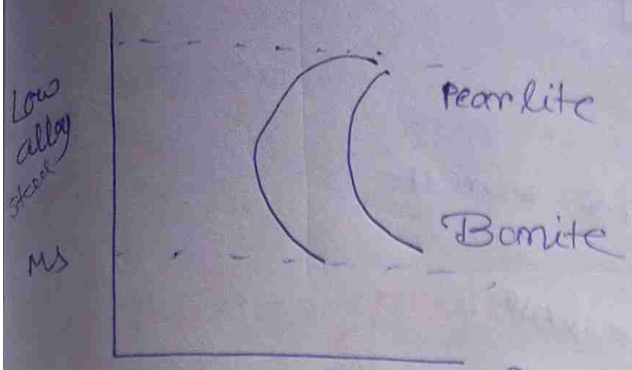
Cr_3C_2

→ 0.03-0.05 Cr, Ni . 8% or more,
Austenitic Stainless steel. (daily useable)
Ferritic Stainless steel (manufacture of Steam Turbine bled)

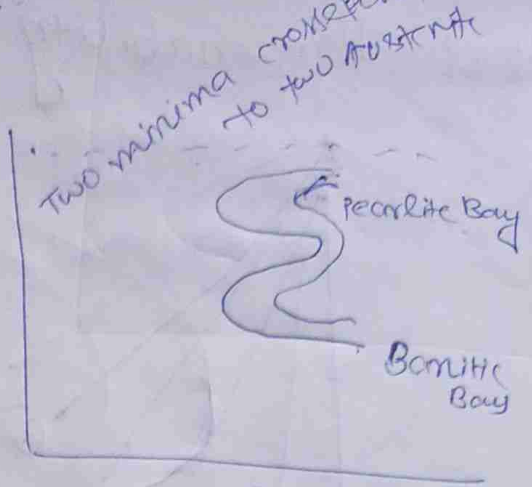
Cr
18/8 Ni → ASS
0.03 → 0.05

(ii) Martensitic stainless steel.
→ (surgical tool)

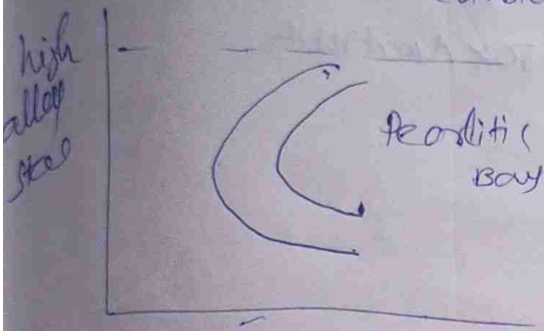
Effect on Alloying element TTT diagram:



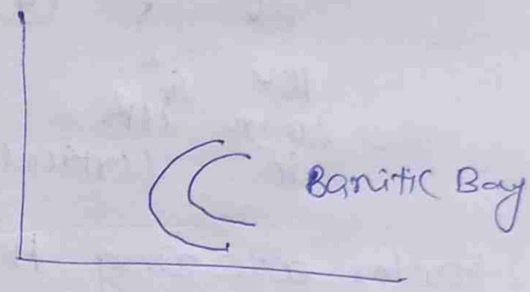
i) If carbide forming alloying elements are present in place of cementite ~~der~~ it will be complex carbide.



ii) Special case



iii)

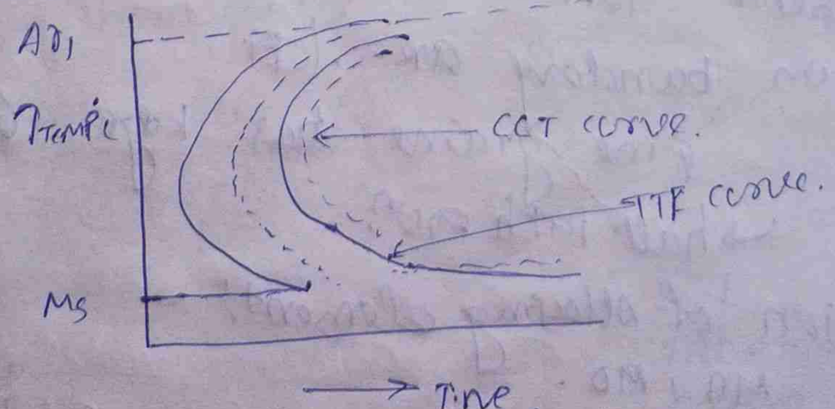


iv

If the nature of alloying of element here Ms temp is ~~lower~~ ~~than~~ bellow 0°C, bainite is also gone down below 0°C so that why bainite Bay is not present.

Ms temperature is above 0°C / room temp does not fever ~~Pearlite~~ Pearlite.

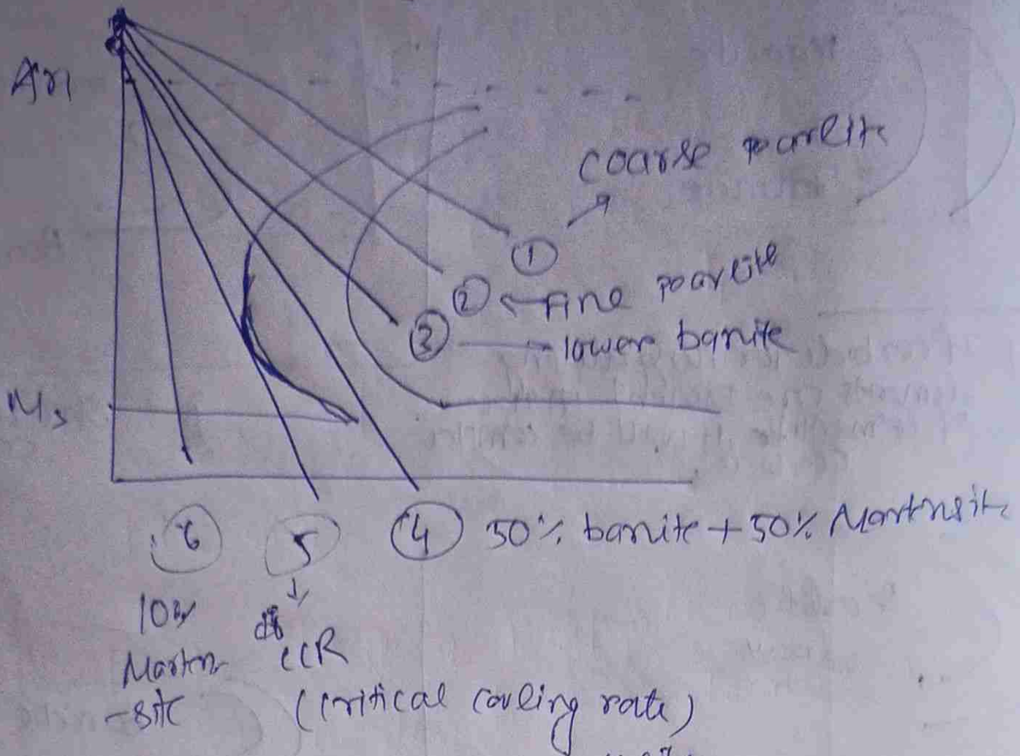
CCT diagram:



ΔT (degree of undercooling) ↑ increase

t Incubation period that also increase

Heat ~~Hardenability~~ Hardenability :- ability to harden.



Factor affecing Hardenability

(1) C → contein
%C ↑ → hardenability ↑ possible → brittleness ↑
It is not practiclele

② Grain Size → coarse grain (reduce tendencies of pearlite)
Nucleation of pearlite takes place at austenite grain boundary.
pearlite formation is favored by large grain boundary area.
Fine grains has large G.B area.
↳ hall-patch eqn.

Addition of Alloying element:-
Mn, Mo.

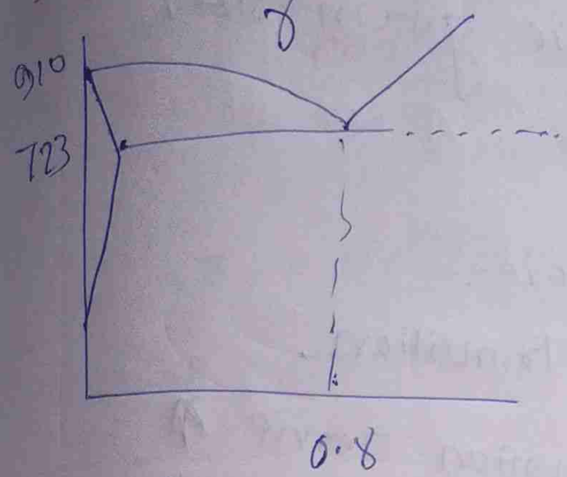
Additin Co → decrease hardenability.

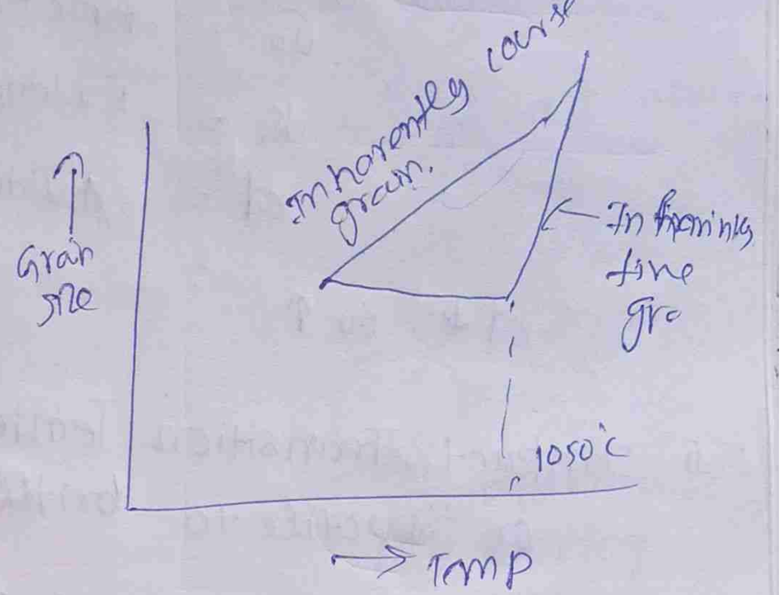
HSS → 18 4 1
W Cr Ba
Mo

Handfield Mn steel: Stone cracker.
→ Pointed rail in Track change

14 → 12 % Mn
1.1 % C
} Non Magnetic. [equally tough & equally abbrasion resistance)

Austenite grain size:-





Transformation should occur at 723°c pearlite → Austenite.

Than size of the Austenatic grain is called original austnitic grain size

In real sitution, pearlite to Austenite transformation takes place slightly above AC1? Above AC1
i,e pearlite to Austenite.

→ To ensure complete transformation

— To ensure homogenity of Austenite.

· * Actual Austenatic grain size

Steel:

Inherantly coarse grain steel

Inherently fine grain steel.

This is due to pracente of carbide, oxide & Nitride at the grain boundaries

Importance :-

i)
$$\sigma_y = \sigma_0 + \frac{K}{\sqrt{d}}$$ Hall-petch eqn.

σ_y = yeild strength

σ_0 = frictional stress,

K = Extend of dislocation.

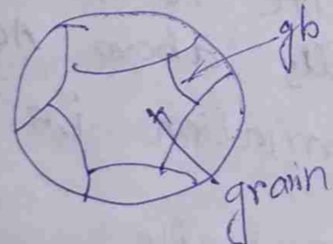
d = Austenalic grain size,

$d \downarrow$, $\sigma_y \uparrow$

ii) Impact Transition Temperature.
or ductile to brittle Transition.

Grain size $\uparrow$, Impact Transition Temp $\uparrow$

III) creep strength (high temp strength)
equi-cohesive temp



at this temp
gb = grain interior.

above e.c.T The grain size $\uparrow$ creep streent $\uparrow$

below equi-cohesive Temp Grain $\downarrow$ creep strength $\uparrow$

IV) Fatigue strength: ability to withstand cyclic loading.

Fine grain size, higher fatigue.

• Hardenability: • hardenabi

grain size ↑ hardenability ↑

Determination of Austenite Grain Size:

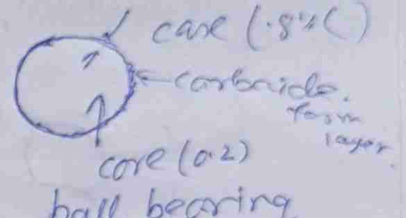
For revealling austenatic grains.

Metallographic method

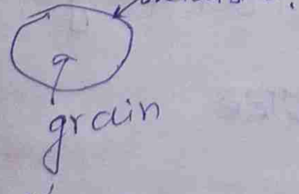
change of composition take place. | No change in composition

(I) case carburizing

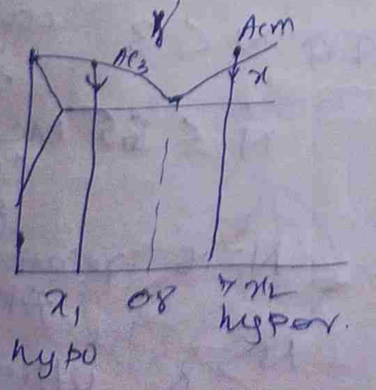
II oxidation



Oxidation:-



#



Hypo

proeutectoid α ferrite start ppt

→ Martensite

Austenite grain

proeutectoid α ferrite

Hyper At x_2

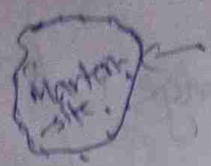
Martensite

proeutectoid cementite.

A1 0.8% C

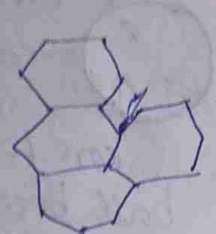
There is no proeutectoid phase present.

extent heat treater
with special heat treatment



cementite nodules are developed along the g.b

3. By comparing with standered ASTM chart.



Hexagones of diff size.

ASTME 112-63

or IS 4748-1968

$$n = 2^{N-1}$$

n = No of grains / sq inch at Magnification of 100X

N = Austenatic grain size

Grain size No (N)	n
1	1
2	2
3	4
4	8
5	16
6	32

N < 3 carse grain

N ≤ 5 Medium carse grain

N = 6 relatively fines

N > 8 ultra fine.

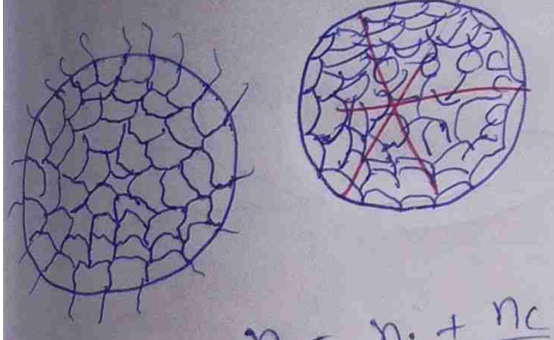
ASTM Standard E 112 – 1985   here ASTM has modified the formula as

$$G = -2.9542 + 1.4427 \ln n_a$$

G = grain size No.

n_a = Number of grains / ~~per~~ mm^2 at 1×

I Jefferies Planimetric Method for equiaxed grains



Area of cross-section · 5000 mm^2

m = magnification should be such that at least 50 grains are inside x-section

$$n = n_i + \frac{n_c}{2}$$

$$n_a = 2n\left(\frac{m}{100}\right)^2$$

$$G = -2.9542 + 1.4427 \ln n_a$$

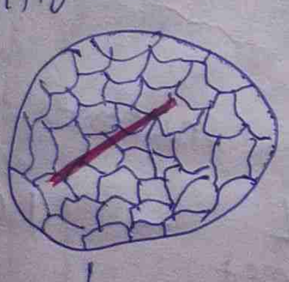
n_a : Number of grains / mm^2 at 1×

n = Total no of grains

II Heyn's intercept Method:

Not for equiaxed grain but ultra fine grains

e.g. High speed steel · N = 10 – 12



length intercept = 0.005 mm at 1000×

so the high magnification is taken at least 0.5 mm^2 of actual sample is covered

10 readings are taken then the average value is taken.

Point ends = $\frac{1}{2}$

Full Intercept = 1

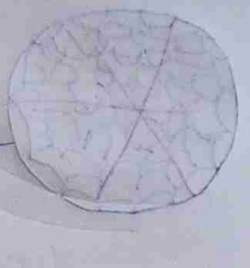
No ~~to~~ of grains per inch at $1000\times = \dfrac{I}{0.005}$

I = mean intercept length. $= 200I$

No of grains per square inch² at $100\times = \left(\dfrac{200I}{100}\right)^2$

$n = (2I)^2$

$n = 2^{N-1}$



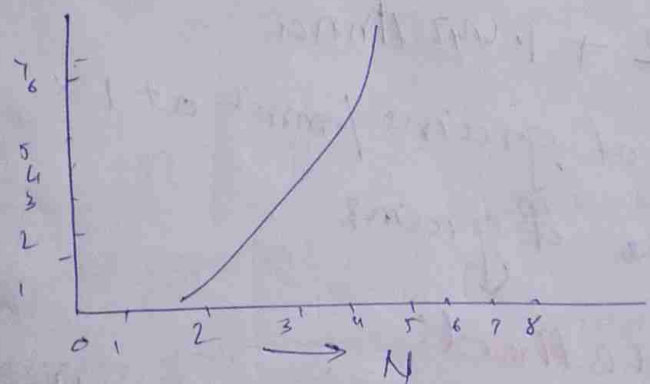
$(2I)^2 = 2^{N-1}$

$2\log I + 2\log 2 = (N-1)\log 2$

~~N~~ (2 log 2I.

$N = \dfrac{2\log I}{\log 2} + 3$

I



→ N

ASTM grain size.

IV Shepherd's Fracture Test Method.

Austenite (grain size)

↓

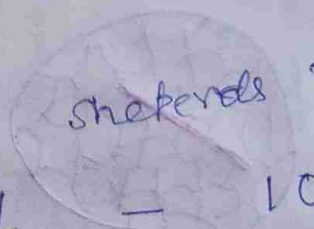
quenched for hardening

↓

Fractured

↓

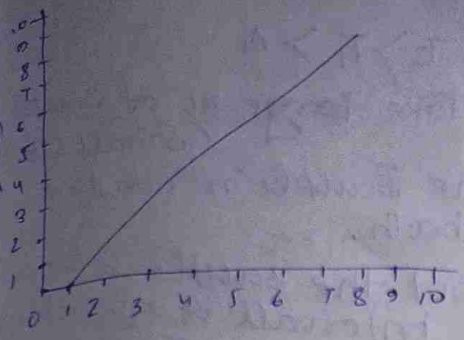
Fractured surface (grain size)



Shepherds fractured No

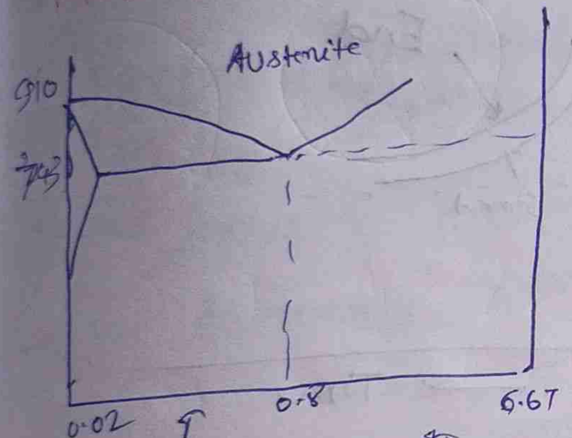
1 — 10

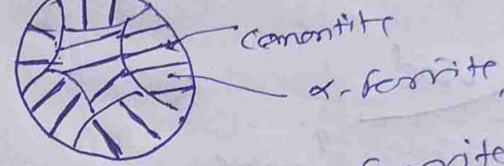
Coarsest Finest



Sheferd's fracture
1–10

Mechanism of pearlite → Austenite transformation.

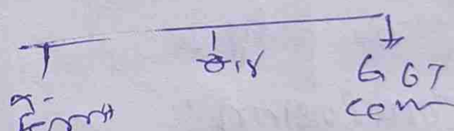




width of α-ferrite lamella is ≈ 7 times more than that of cementite.

proeutectoid α ferrite + cementite

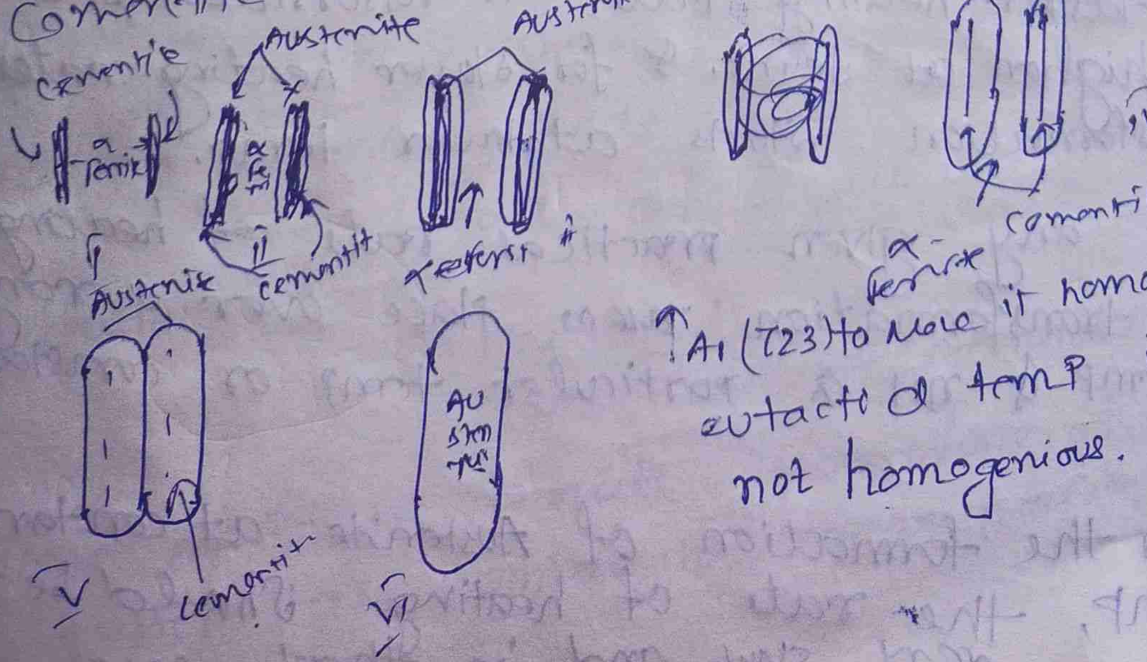
α ferrite + proeutectoid cementite.



$f_{\alpha\text{-fer}} = 0.88$

$f_{cemt} = 0.12$

density of α-ferrite & cementite is ≈ equal



↑A1 (723) to More it homogenious, eutactoid temp is not homogenious.

Kinetics of Pearlite to Austenite Transformation

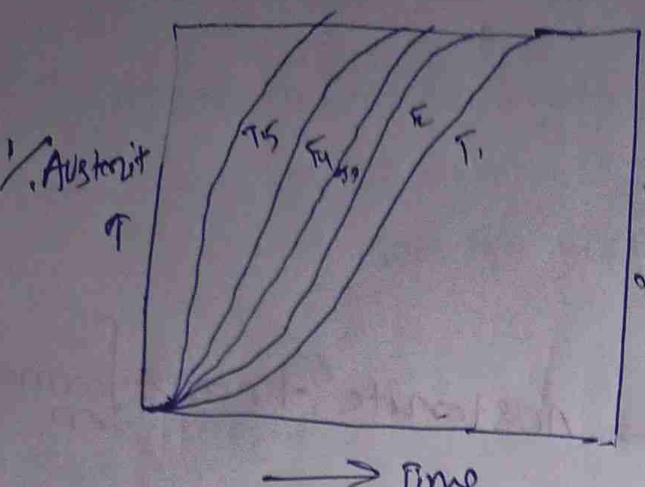


Fig. 1

$T_5 > T_4 > T_3 > T_2 > T_1 > A_1$

Step 1 → Take large no of sample (small size)

Step-2. Dip the sample in constant temp bath.

Step 3 :- Take out the sample after specific intervals & quenching.
↓
Martensite

% martensite form will depend of how much % Austenite was form before quenching

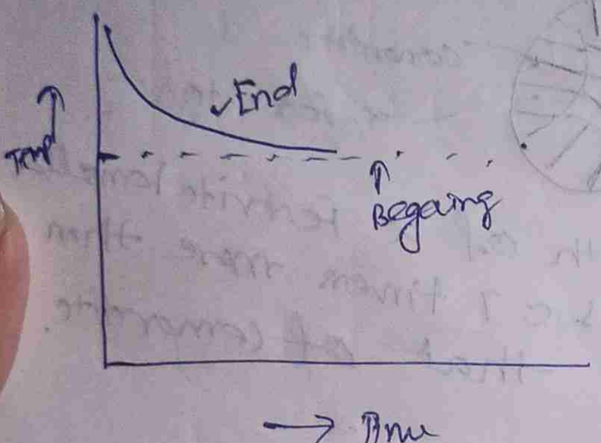


Fig. 2

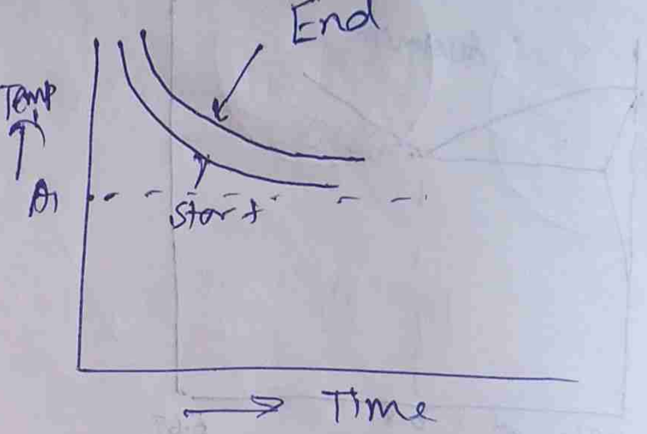


Fig. 3

Conclusion :-

1. Transformation is compleated in a short period at higher period.
2. For faster heating rate, Transformation starts at higher ~~at~~ temp. & for slower heating rates transformation starts at lower temp.
3.
(ii) For any given practical rate of heating, the transformation takes place over a range of temp & not a particular temp or constant temp.
(iv) For the formation of Austenite at constant temp, the rate of heating should be very slow and in that case

the two curves of Fig-3 will merge the temp A1.

• The Rate of pearlite → austenite transformation depends upon the Transformation Temp & Time. Other factor affecting kinetics of pearlite to austenite transformation.

Mechanism → Nucleation & growth. Austenite Nucleation at interface of α-ferrite & cementite.

Rate of Nucleation & growth can be ↑ by ↑ the Interface area.

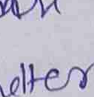
Now How to increase the interface area?

→ I. By increasing cementite content.

cementite content can be ↑ by increasing % C

That's why cementite formation Transformation to Austenite is faster in case of high carbon steel.

II. by decreasing interlameller spacing. distance b/w two successive lameller.



If the Interlammer spacing ↓, carbon has to travel smaller distance. rate of becaus of it all depant upon diffusion carbon.

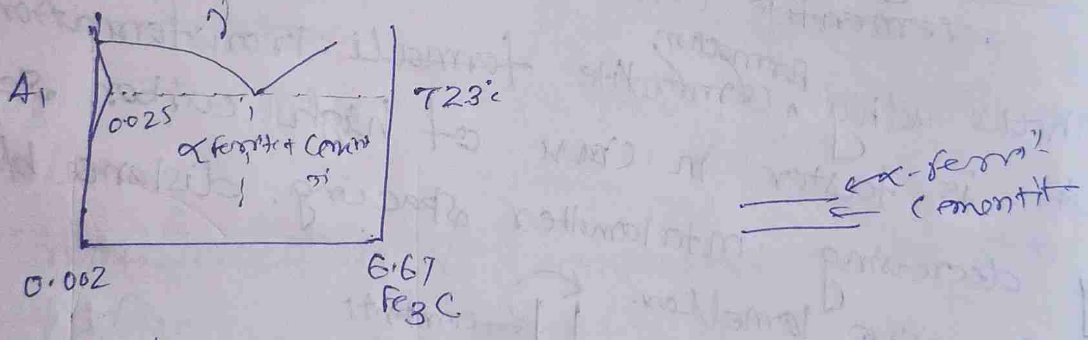
fine → coarse pearlite → Interlameller space ↑

Incase of finner pearlite. Trasformasion to Austenite is faster as comper to coarse pearlite.

Pearlite may also occur granular pearlite
→ globular pearlite. } Interface area is small.
→ Transformation to Austenit will be slower.

In case of Alloy steel.
Suppor carbide forming elements are parsent complex carbides will be & formed,
complex carbide donot dissolve easily in austenite matrix, for this much higher transformation is required.

Austenite → pearlite (Mechanism)



Just below 723°c

0.025 0.8 6.67

- annealing
→ normalising (air)

0.8 × 0.12
= 0.1

~~0.8~~
$0.8^2 \times 0.88$

= 0.7

α-ferrite + cementite first at austenite grain bandary.? provided A is present active nucleaus.? in the final Microstructure.

-it must have some lattice orientation relation -ship with parent phase austenit.

Meh'ls hypothesis:-

(i) orientation relation b/w pearlatic ferrite & parent austenite is different from that of proeutactoid ferrite and parent austenite, therefore, ferrite cannot be active nucleus. for

(ii) formation of pearlite is affected by the presence of undissolve cementite particles. where as the presence of ferrite doesn't exhibit any such effect.

(iii) proeutactoid cementite as well as pearlite cementite are, in general, parallel to one high index plane of austenit.

Smith hypothesis:-

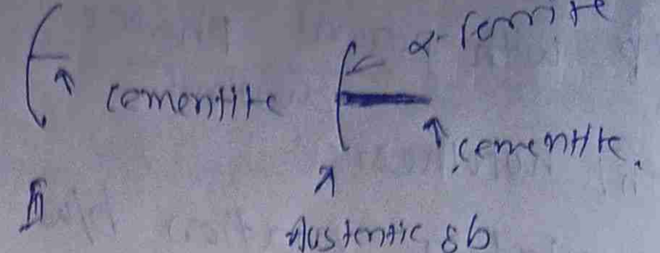
(i) pearlatic ferrite as well as pearlatic cementite can have any orientation relationship with the parent austenite. except for those which are allow the formation of interface which the parent austenite. partially co-herent with

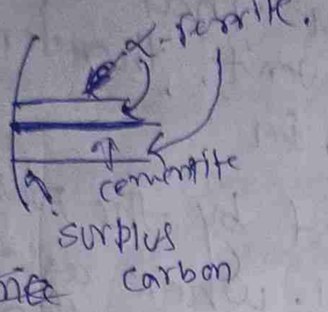
(ii) Both cementite & ferrite can be active nucleas & concequently, formation of pearlite can be initiated by the either of the two nucleate ~~fast~~ in first.

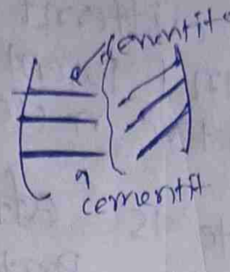
(iii) In general, ferrite will nucleate first in case of hypoeutactoid steel and cementite will neucleate first in case of hypereutactoid steel.

Hull-Mehl's hypothesis

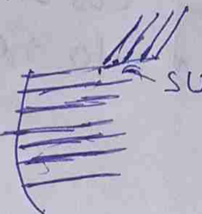
austenite g.b





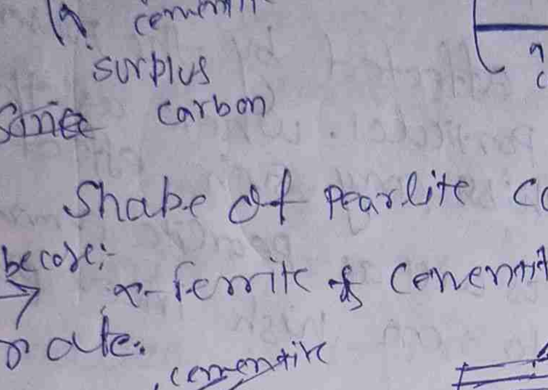


Shape of pearlite colony is spherical?
because:
→ α-ferrite & cementite both grow at the same rate.



∴ Edge wise growth of pearlite col.

Kinetics of Austenite ⟶ pearlite.



at A_1
$G_{Austenite} = G_{pearlite}$,

$\Delta G = 0$.

when $\Delta G = -ve$

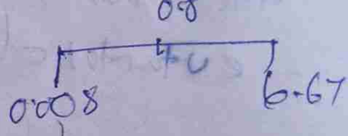
$G_{pearlite} - G_{Austenite} = -ve$

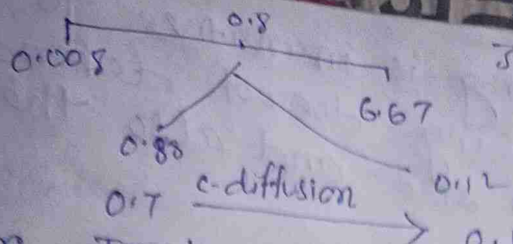
Transformation to pearlite depends upon degree of undercooling, i.e. $A_1 - T$

A) rate of Transformation to pearlite depends upon degree of undercooling. Transformation rate

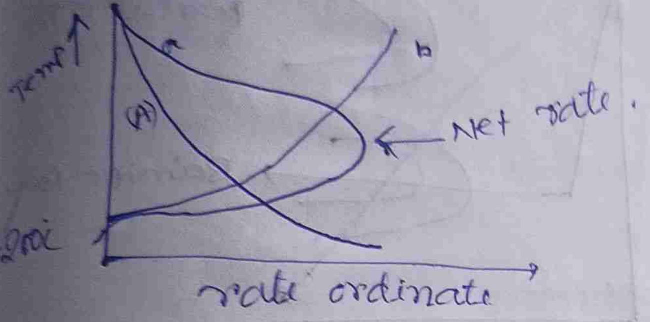
Lower the Temp of Transformation will be faster.

α = ferrite + cementite.





(b) At lower Temperature the rate of diffusion of carbon will be slower at 200°c it is almost negligible.



since both are oppose to each other. transformation ~~Rate~~ will occur at the net rate

Effect of Alloying Element:-

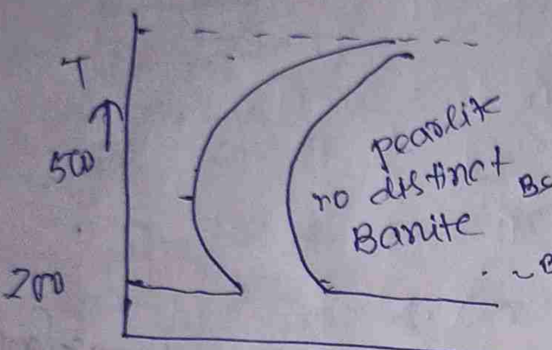
with increases in degree of undercooling, rate of transformation to pearlite ↓ in the presence of havier atoms of alloying element.

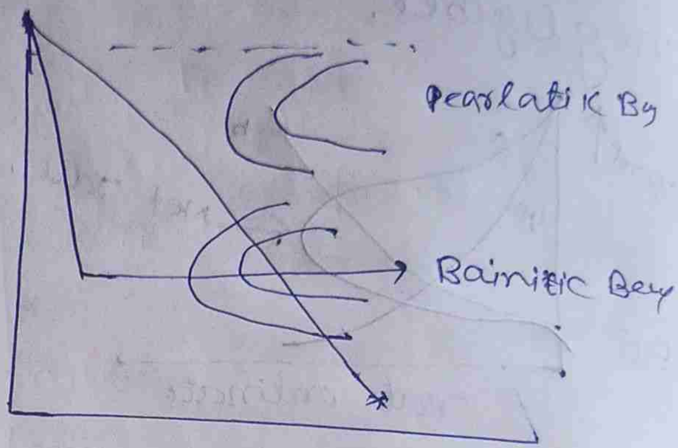
Intelameller spacing - depends upon Transformation Temperature provided other parameters are same, Interlameller spacing will be small if transformation temp is lower i.e degree of undercooling is larger. since for stronger steel, interlammeler ~~Steel~~ spacing should be small, lower temperature of transformation are desired.

In case of Alloy steel, Transformation Temp is always highter that means in the case of alloy steel interlammeler spacing is larger.

Interlameller spacing is insensitive to structure.
Interlameller spacing doesnot depend upon the austentic grain size and also the homogenity of austenite.

Bainite Transformation:- α ferrite + carbide
- No lameller str.





(i) - 0.8% C Steel
Perlatic & Banite Region overlap banite cannot be obtained by continious ~~cost~~ cooling.

(ii) Specific Alloy steel
banite can be obtained by continious as well as isothermal transformation.

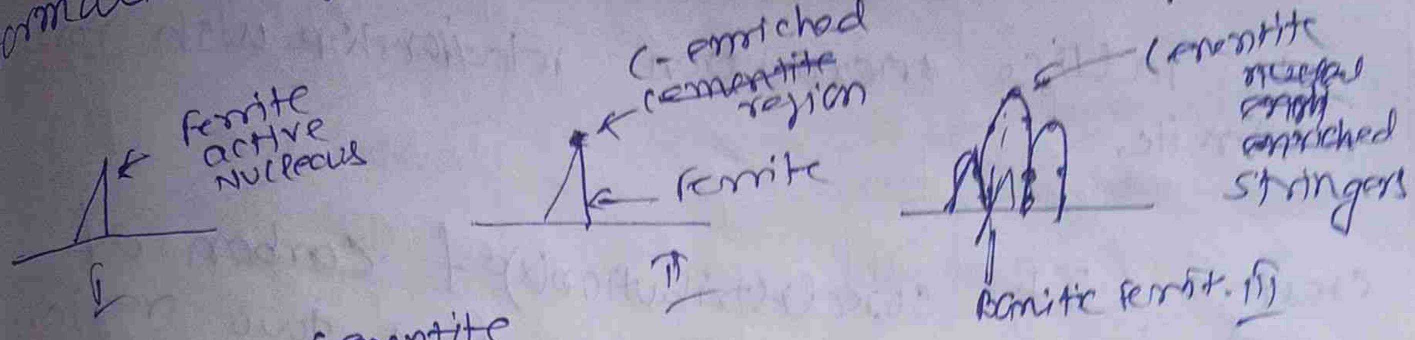
Mechanism of Transformation:
- 500°C 'c' diffusion may take place.
200°C
↓ rate of diffusion of 'c' will be slower.

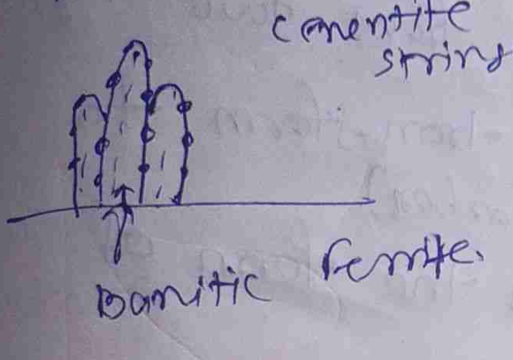
rate of diffusion of Fe or other metallic atoms is negligible or nil.

alloy steel - ε-carbide
Fe_xC, $Fe_{2.4}C$
+
Shear Mechanism.

* In the case of Banite carbide is very finely distributed higher Magnefication is required to observe.

formation of banite is complex process.





IV

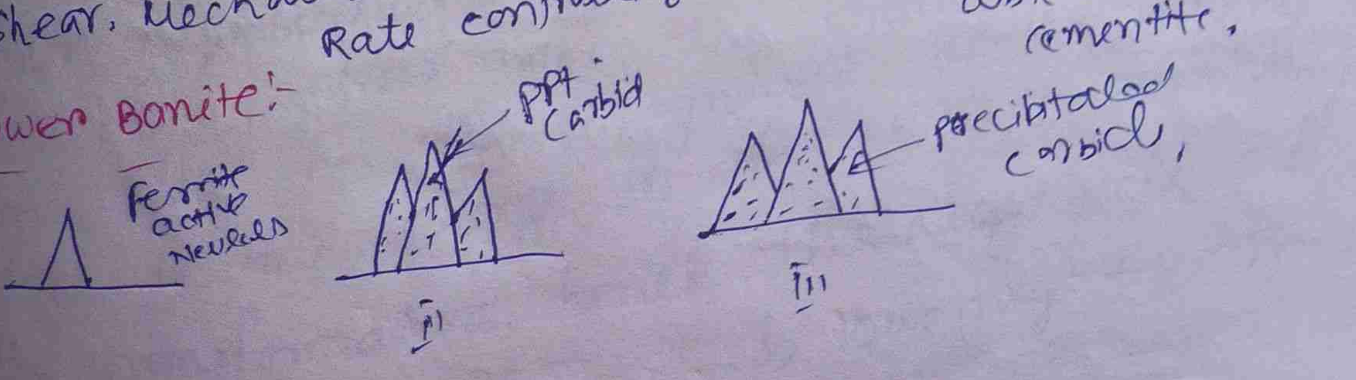
(I) There is lattice orientation relationship b/w ferrit & parent austenite.

Step-II ; re-distribution of carbon takes place in austenite, low carbon austenite, high carbon austenite. This result in the ~~step~~ setup of carbon enriched. stress.

Step-III . cementite ppt out of carbon enriched region in the form of stringers. Low carbon austenite transforms into ferrite by shear mechanism.

Rate controlling step = diffusion of carbon away from the high C austenite & form cementite.

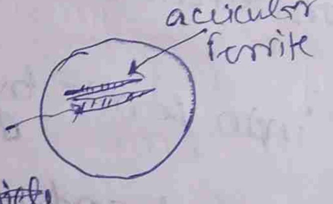
Lower Banite:-



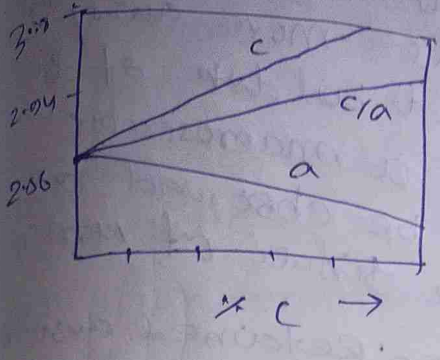
Step I:- Ferrite is active Nucleus, bean ferrite is lattice orientation relationship with parent austenite.

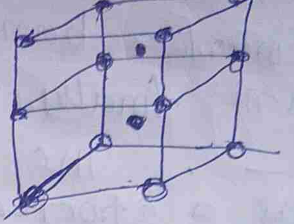
Step II : It, so redistribution(x) of carbon of
x { Taking place inorder to from two region
- Low carbon austenite transform to Supersaturated ferrite. (with carbon)
'c' will precipitate out in the form of ~~carbon~~ carbide.
ppt. carbide axis is at angle 55° with the axis of bainite ferrite.

In the case of alloy steel for ~~ppt~~ precipitation of ϵ-carbide has been observed, ϵ carbide cannot precipitate out from austenite.

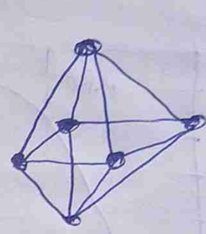


Martensitic Transformation





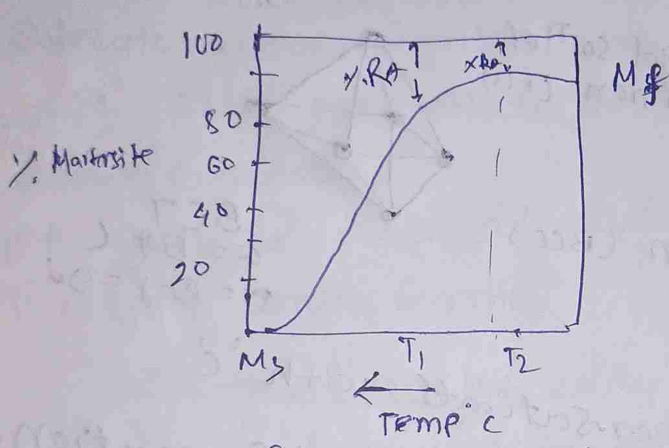
Austenite . Saturated solid solⁿ of carbon in γ iron (FCC)
↓ quenched ↓
(Martensite) α iron (BCC)



composition is same.
This α iron is supersaturate with C
Martensite is a diffusion less transformation.
~~[illegible]~~ It is a displaceble transformation that takes place by co-oparable moment of a large Number of neighboring atom. each atom moves over a distace which is less than 1 interatomic distance. in this process, the atoms maintain their neighborhood undistrbed. A large driving force is required for the transformation to take place. This the magnitude of the driving force is the change in free energy accompanying the transformation. hence the Magnitude of driving force in by lowering the Trans-formation Temp.

Although the displacement of invidual atom is less ~~than~~ ~~inter~~ 1 interatomic distance. The total displacement increases as one move away from the interface boundary. such a buildup of displacement finally results in a macroscopic slip. The slip can be observed as a relif a structure on the surface of Martensite.

RA = Retained austenite (No Stable Phase)



The Transformation ~~in~~ to Martensite start at a temp M_s then it proceeds along a range of temp. ~~at the~~ among of Martensite form it depends upon the ~~Mar~~ transformation temp. (T_1)

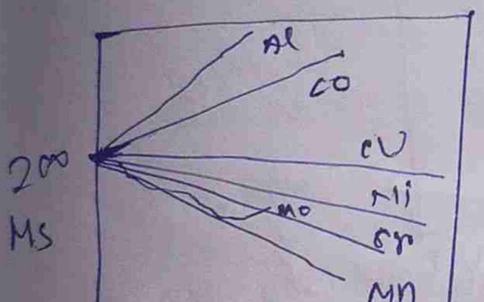
∴ Amount of Martensite transform depends upon nucleation of ~~new~~ new plates for Martensite and not due to growth of Martensitic plates. ~~at~~ even is M_f is reached some Austenite is not transforme to Martensite that's called retained Austenite.

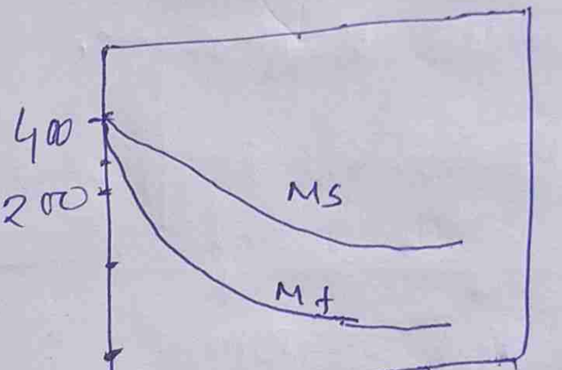
(m_s, HCS)

The Transformation to Martensite begains in fraction of Microsecond and completes in fraction of Millisecond. This means rate of Martensatic Transformation is independent to of Transformation Temp.

Ms & Mf temperature.

$$M_s = 561 - 474(\%C) - 33(\%Mn) - 17\%(\%Ni) - 17\%(Cr) - 21(\%Mo)$$





Ms Temp does not depend upon cooling rate but Ms Temp depends upon the chemical composition of the steel and the austenitization temp.

factor which effect Ms Temp ⇒

- second factor which effect Ms Temp ⇒

If Austenitization Temp is high more and more carbide will dissolve as a result carbon content will increase, Ms is lower.

(ii) If the austenitization temp is high, grain will take place coarse austenitic corresponding grain size ~~result~~ raises Ms temp..

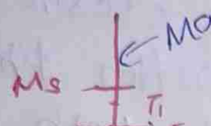
M_f is ↓ with increes carbon content.

- M_f is also lowered if cooling rate is very very slow.

Rate of Transformation arand M_f is very very slow that's why in TTT diagram, M_f Temp is not mention.

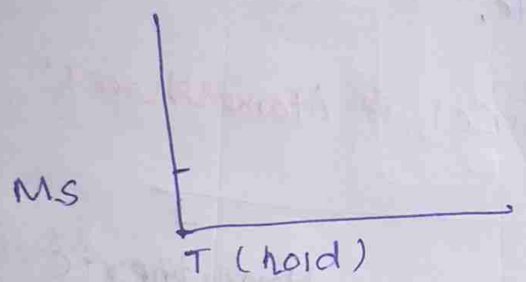
of applied stress favors

Athermal Martensite



← Martensite will form.
Martensite will form again
all 'c' steel.

Isothermal Martensite



Low 'c' Fe alloy.
high alloy.

'Lath' Martensite:-

⇓

Long thin strip from one grain boundary to another grain boundary.
Long - (Across gb)

thickness :- 0.10 to 0.20 μm

Plate Martensite (Lenticular looks like a lens)

Length :- Across g.b

Hardness of Martensite:

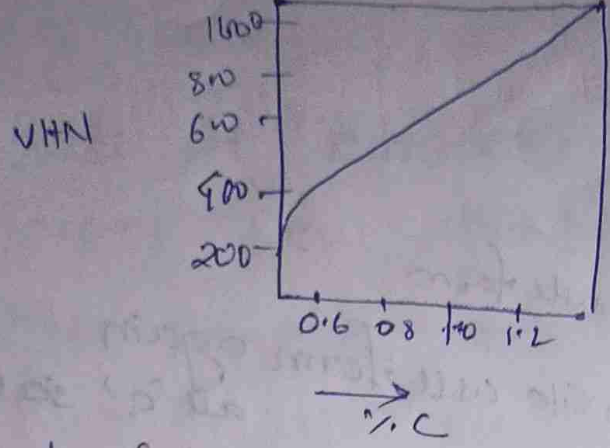
Reason behind hardness of Martensite.

(i) 'c' content increases · hardness ↑

(ii) Due to presence of strain within α-iron lattice.

(Strain in α-iron ~~is~~ due to supersaturation of α iron by c atoms)

(iv) Plastic deformation of parent austenite surroun-
-ding the Martensatic plate.



If Ms is Temp is lowered % of retained austenite increases.
Retained Austenite is not a desired phase, its softer phase.

So high 'c' content & low 'c' both are not desir-
-able only medium c steel is more suitable for Harden Martensite.

Heat Treatment Furnaces & Atomosphores.

- Use
- Source of Heat
- Type of operation (work)
- Atmospheric

Use →
Annealing furnace.
Hardening Furace
Tempering
...

Source of Heat:- (Solid fuel is not used)
— Fuel oil use only, gasious fuel (Natural gas, BF gas + cokeove gas)
Electrical energy (Electrical furnae

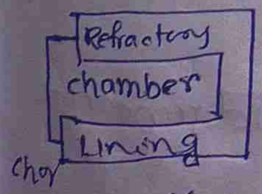
Batch type
- Muffale furnae,
- Pit furnae
→ Bogie furnae

Type: continius furnac. Batch furnac

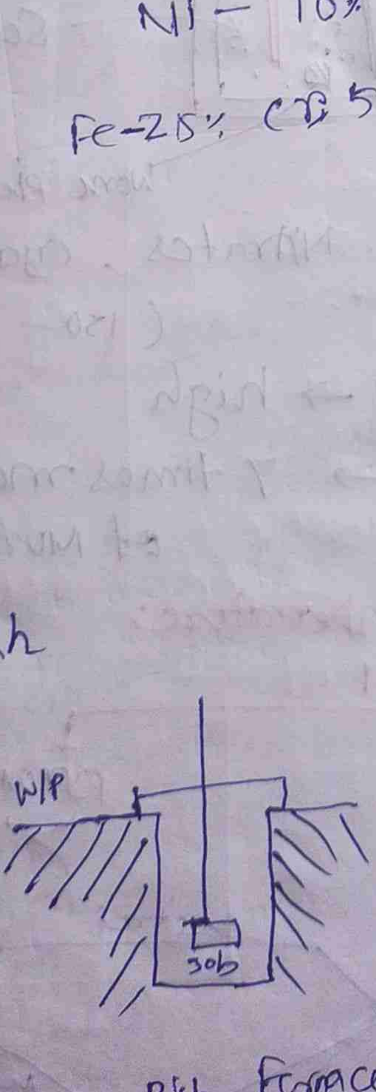
Atmosphe: Open air, controlled atmosphere.

Wires/Rods:

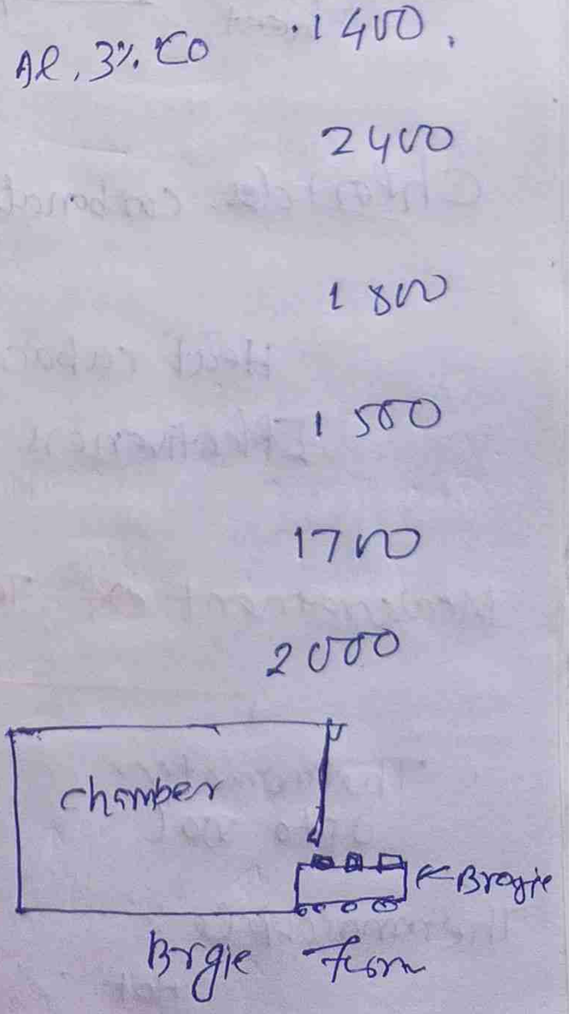
		upto
1) constantan	- Cu - 40% Ni	900° C
2. Nichrome - I	Ni - 20% Cr	1100° C
3. Nichrome - II	Ni - 24% Fe, 16% Cr	950° C
4. Alomel	Ni - 3% Mn, 2% Al, 1% Si	1200° C
5. Chromel	Ni - 10% Cr	1200° C
6. Kanthal	Fe-25% Cr, 5% Al, 3% Co	1400.
7. Tungsten		2400
8. Molybdenum		1800
9. platinum		1500
Thermo cuple 10. Pt - 10% Rh		1700
11. Graphite		2000



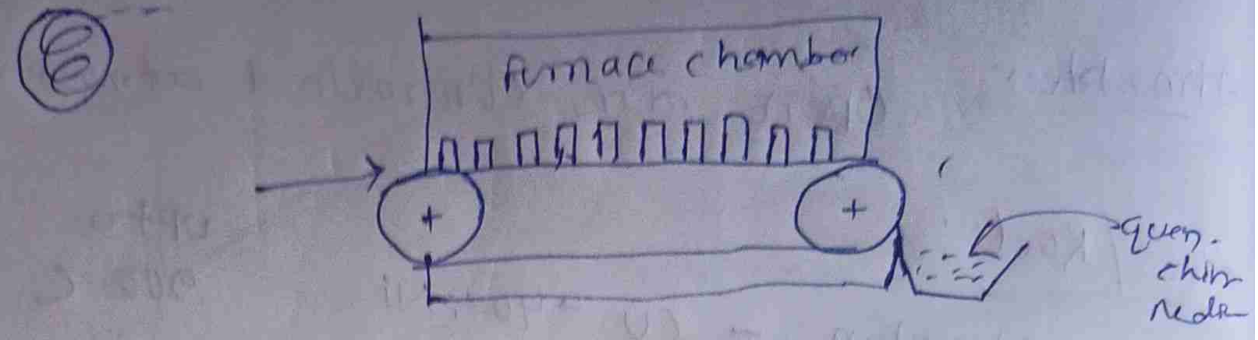
Muffale



Pit Furnace

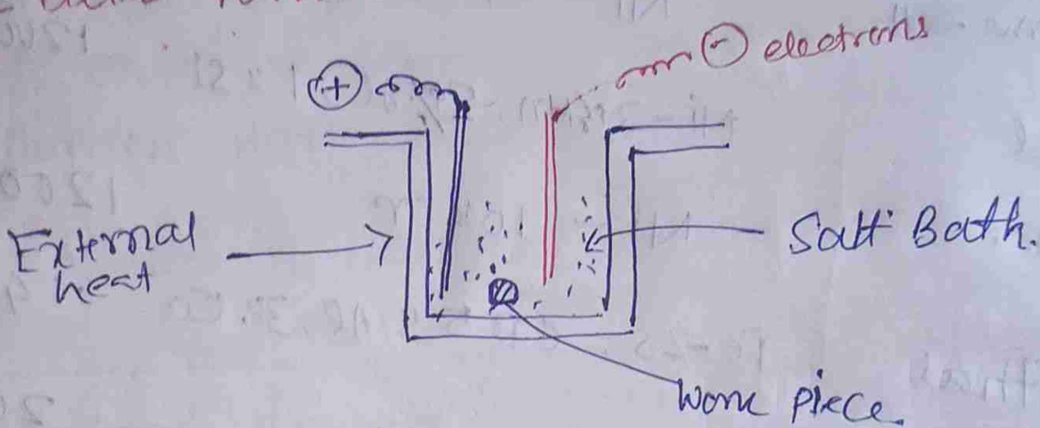


Bogie Furn



continuous type
(Hardening Purpose)

Salt Bath furnace:



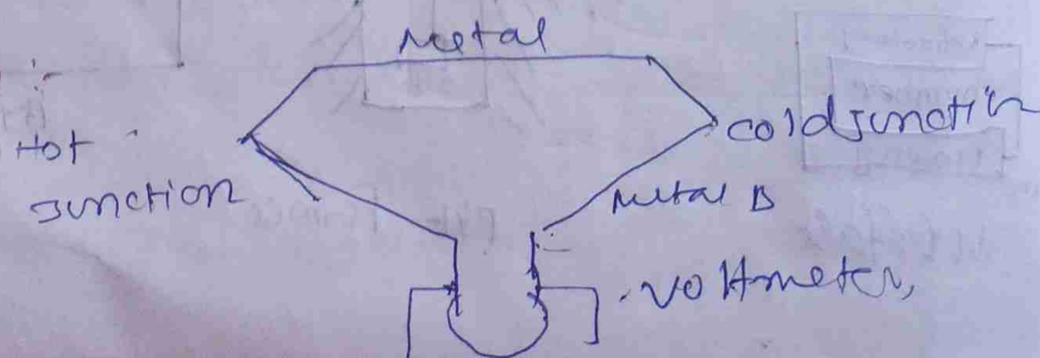
Chlorides, carbonates, Nitrates, cyanides.
(150 – 1300°C)

Heat capacity → high
Effectiveness → 7 times more than that of Muffale.

Measurement of Temperature:

Thermometer upto 500°C
pyrometer if > 500°C

Thermocouple :-



Thermocouples

- Base Alloy
- Noble Alloy.

Requirement of Thermocouple Materials.

(i) The metal should be homogenious.

(ii) The material should be resistant to oxidation & corrosion.

(iii) The Thermal conductivity of the material should be high.

(iv) The formability of the metal should be good so that any —

(v) Melting point of the materials should be higher than the working temperature.

(vi) The EMF should increase with increase in temperature difference.

(vii) There should be linear relationship b/w EMF & Temperature.

(viii) The Induced EMF should be sufficiently large.

(ix) The Induced EMF should not be reproducible.

(x) The Material should not be very expensive

(xi) chemical composition of some alloys use as thermocouple

(i) constantane

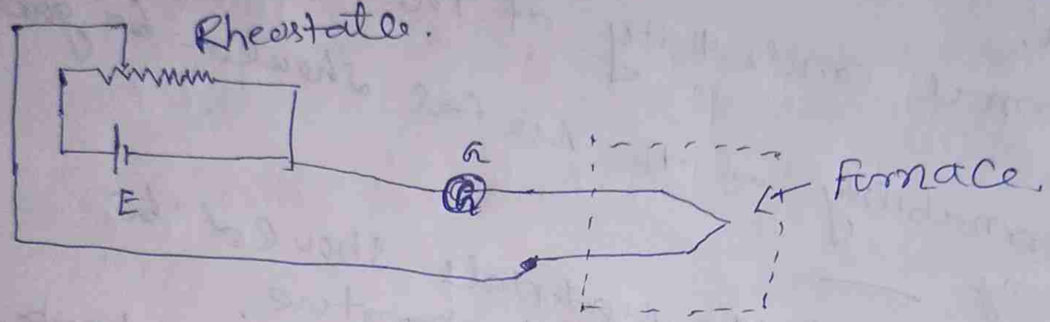
(ii) chroman

(iii) alumen.

(iv) Pt- Rh- Alloy.

For every higher temp following compo-
-sition can be used, Tungstan - Mo, Tungstan-
Rheneium, Tungstain - 26% Rhenium.

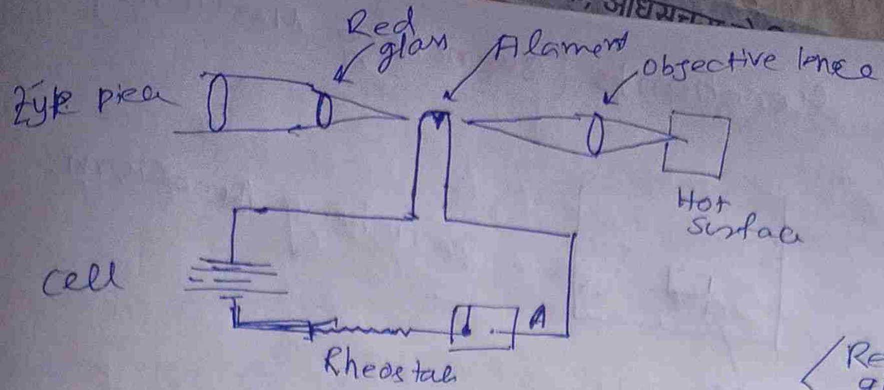
(v) Mo - Rhenium, Tungstein - Irridium, Irridium-
Irridium. Rhodium alloy,



Caliberation :-
Hot Junction is deep on the just cold Metal.
and temp reading is taken.

cold Metals

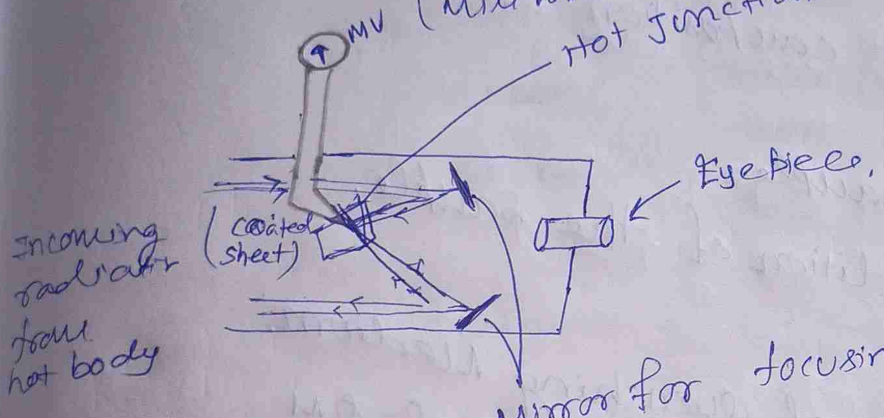
Al	600°C.	Pt	1773.5°C
Sb	630.5°C	Rh	1966°C
Bi	271.3°C	Ag	960.5°C
Co	1480°C	Sn	231.9°C
Cu	1083°C		
Au	1063°C		
Pb	327.4°C		
Ni	1453°C		



Optical pyrometer

<Red glass> → For Monochromatic, λ

Indirect Method



coated sheet

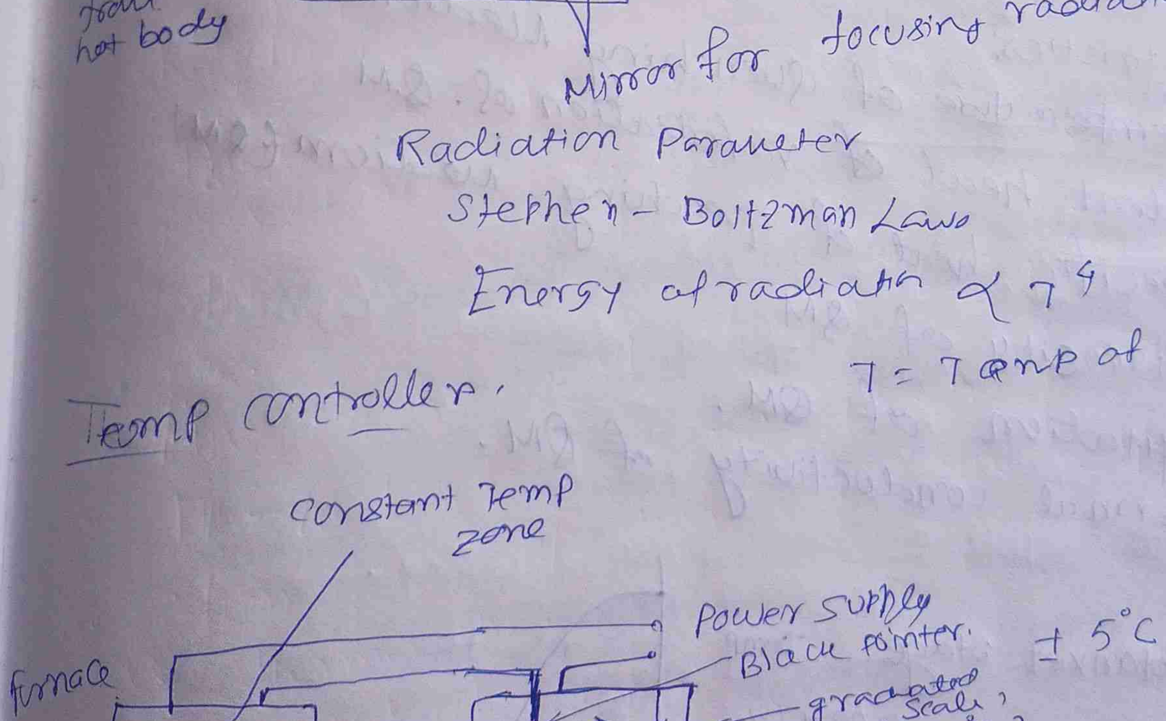
Radiation Parameter

Stephen - Boltzman Law

Energy of radiation $\propto T^4$

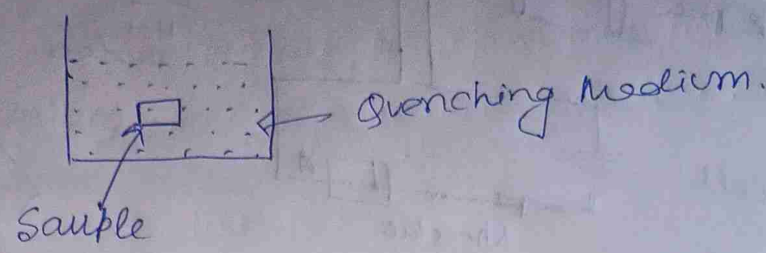
T = Temp of sample.

<u>Temp controller.</u>



Temp controller

Quenchants (Quenching Medium)



cooling rate:-

— charecterstics of the quenching Medium

— chemical composition of steel/ non-ferrous alloy.

→ Design of sample.

— Surface condition of the sample.

Charectorstics of quenching Medium:-

(I) Temperature of quenching Medium.

(II) Latent heat of vaporization of. Q.M.

(III) Specific heat of quenching medium (QM)

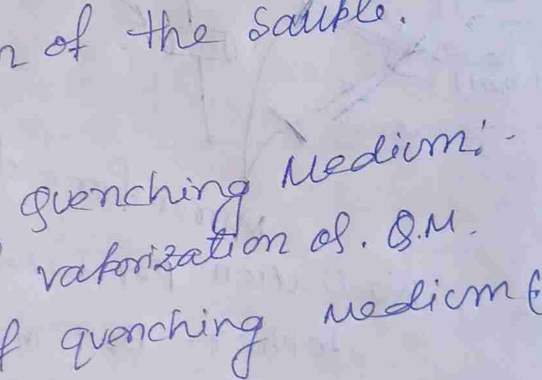
(IV) viscosity of QM

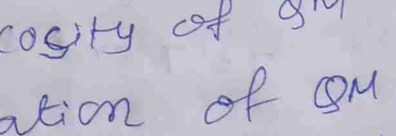
(V) Agitation of QM.

(VI) Thermal conductivity of QM.

Stag-1:-

Vapor blanket stage





Stage-2 :
Liquid boiling Stage:-

← vapor film disappears.
direct contact of liq

Temp of Sample > B.P of Q.M

- appearance of boiling
- cooling rate is fastest.

Stage-3 : 'Liquid-cooling Stage.
Temp of Sample < B.P of Q.M

- Slowest cooling

charecterstics:

(i) Temp of QM:

Water 20-40°c - cooling rate will be ~~Slower~~ faster

Mineral oil 41-150°c → cooling rate will be slower

(ii) Latent heat of vaporization of Q.M:

Lower → It will add stage-1, rate of cooling will be slower.

- loss of quenchat ; Hazardous.

higher → "

(iii) Specific heat of Q.M:

Less → Temp of QM will increase, cooling rate will be slower.

high : Mass production

(IV) Thermal conductivity of QM:-

good → proper heat transfer from hot surface of Sample to Q.M will take place.

(V) viscosity:

For good heat transfer or faster cooling rate } Low.

(VI) Agitation of QM:-

↑, cooling rate ↑

(VII) Different Quenchant.

(I) Water:-

20-40°C

Limitation: vapor film does not form until Agitation.

II. Aqous solution.

NaCl, CaCl₂ → brine. | 5-10% in water.

NaCl is crystalized.

vaper film.

Crystalize NaCl Jumped (pinning) in Hot surface, and water vapor film broken.

Advantage:- cooling rate of is faster than Normal water.

Limitation: corrosion action in is on the VAT and equipment.

(iii) Mineral oil:-

Lower viscosity is preferred 40°C

Hot quenching oil → Medium viscosity.

Marquenching oil :→ high viscosity
• 150°C

(iv) Salt-bath

100% $NaNO_3$, 50% $NaNO_3$ + 50% KNO_3.

Molten salt bath

- very effective heat transfer

→ uniform heat transfer.

→ No danger of oxidation, carburization or decarburization.

(v) Air:-

Air is a quenching medium is used when the specimen is Air hardenable die.

(v) Gases:

H_2, He, N_2, Ar

costly, poor efficiency

decreasing order of cooling efficiency.

dangerous

only N_2 can be used as Q.M.

(vii) Synthetic Q.M:

(a) oxy-alkalyne poly glycol based
(b) poly-alkalyne glycol based } water soluble.
(c) poly-viniyl pyrolidon based

Among this (b) is more common

Insteade of water vapor film a glycol film is formed.

This flim (glycol) has got good thermal conductivity

(ii) After some time glycol, is dissloved in water, then cooling takes place stage-2.

Heat Treatment process:

1. Stress releasing — (residual stress)

internal stresses are generated during solidification of Metal & Alloy.

- Mechanical working of metal & alloy (Rolling forging, extrusion)

Machining, short pinning.

Effect:
Cause: Stress corrosion cracking. (

External stress is applied in presence of corrosive media rate of corrosion ↑.

If internal stress are there, stress corosin cracking taking plac.

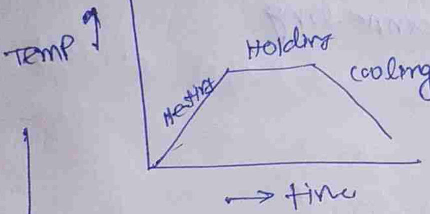
— ~~Worrping~~ warping, dimensional instability

- Fatigue strength may be reduced.

process involve:-
[I] ~600°C, held for specific period, cooled slowly & uniformly

Heating the specimen.

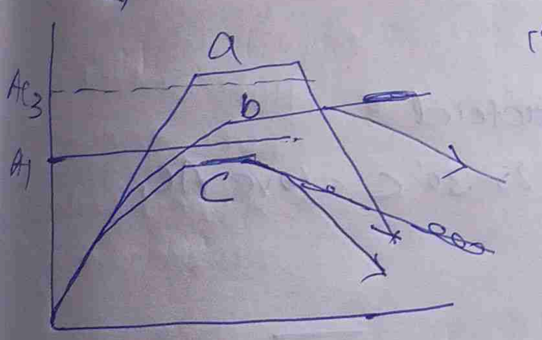
(iii) Annealing:-



(I) Based upon holding Temp (I)

Based upon Phase Transformation (II)

purpose (III)



(a) critical cooling

(b) intercritical cooling

(c) subcritical cooling.

II Based upon phase Transformation:

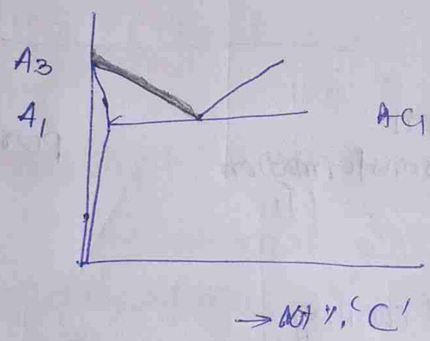
(i) 1st order of annealing (Temp is not fixed. range of Temp) depend upon end process

(ii) 2nd order of annealing.
(it is depend what kind of Phase Transformation taking place. Temp is fixed.

3. Purpose :-

Full Annealing (simply annaling)
- Isothermal annealing.
- Partial annealing
→ diffusion annealing
→ Recrystalization annealing
→ process annaling.
→ Spherodizing annealing.

Full Annealing :-



Hypoeutactoid	& Eutactoid
↑ Heat to a temp 25-30' above AC_3	25-30' C above AC_1
Held —	—
↓ Cooled showly	

Purpose :-
(i) Stress relieving
(ii) Improve ductility
(iii) Restore Toughness
(iv) enhance Machinability.
(v) Improve chemical homogenity.

(vi) Refine grain size

(vii) Remove dissolved gases.

Hypereutectoid:- In this we heat above 30-30°C above A_{c1}, grain ~~coarse~~ coarsening ~~takes~~ takes place, ~~ageing~~ and as coarse during cooling coarse grain & network formation of cementite takes place.

Isothermal annealing:

$A_{c3}+25-30°C$ hypo

$A_1 + 25+30°C$ eutectoid

↓ below A_1 & it held ~~held~~ at temp 500-700°C till pearlite transformation is complete.

↓ air cooling.

Advantag: not Time consuming.

Limitation:
Suitabel for small size. In case of larger size (problem of homogization takes place)

Diffusion Annealing :- * 2nd H.T } Hypo eutactoid Full Anneal | Hyper Normaliz

|→ To remove chemical homogenity

|→ To remove non-uniformity in structure.

Heat treatment of Ingots

heavy casting of Plan

" " of high alloy steel.

Heating ↑ 1000-1200°C ↓ Cooled slowly

slowly

- segregation has been removed

→ structure has been re-fined.

Temp is very hig

grain coarsening → 2nd heat treatment (*) Hypo eutat Full Anne → Hyper eutactoid Normalizing.

Scaling → controlled atmosphere

→ high temp

→ duration

→ cooling is very slow, lengthy

very costly.

rtial annealing

Intercritical annealing

A_1 & A_3 | A_1 && A_{cm}

High C steel.

pearlite surrounded by

Fine pearlite
+
cementite
doesnot form a
a continitus network.

Recrystalization Annealing

- may be an intermediate process or final process

Appliatn → wires, sheets or strips

Annealing Temp (not fixed) below A_1

- it depends upon amount of prior deformation
(compulsory steps)

↓

Genarate defacts
↓
which acts as noclaus size for the nucleation
of strain free grains

It also depends upon chemical composition

→ holding time

→ Initial grain size.

Annealing Temp can be lower if holding time is increased. (not preffered)

higher Temp, less holding perid.

process Annealing:

– Intermediate procss.

Annealing Temp is slightly below re-crystalization temp.

In this procss re-crystilization may or maynot takes place.

cold work → process annealing

→ cold work.

→ cheaper than re-crystalization annealing

Spherodizing Annealing.

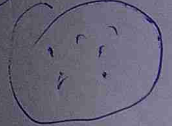
hypo & Eutactoid

Cementite in lameller perlite change to globular shape or spheroid

Hyper:

Free cementite will change to globular cementite or spheroid.

HW P



softness
of cementite
in a matrix of
ferrite.

increase machinability

(1) Heating to just below Ae_1 and keeping it for a prolong period till all cementite has transformed into spheroids.

(ii) Heating just above A_1 & then cooling just bellow A_1 → repeating this cycle for many times till the transformation is achived.

(iii) This involves heating just above A_1 and then cooling it just bellow A_1 & holding it at this temp for a prolong period till transformation is complete.