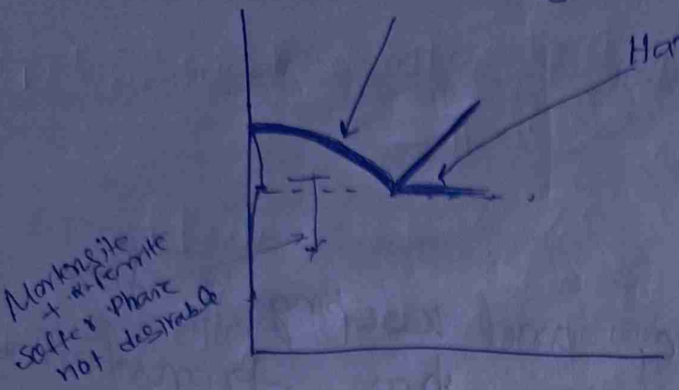
Normalizing:-



Purpose of Normalizing:-

(i) To improve mechanical properties.

(ii) To refine grain size.

(iii) Improve Machinibility

Normalizing involves heating to a temp $Ae_3 + 40-50°C$ in case hypoeutectoid, $A_1 + (30-40°C)$ in case of eutectoid steel. $Acm + (40-50°C)$ in case of hyper eutectoid steel.

Advantage: High Molding temp
- Better Homoginity of Austenite.

↓

Air or Agited air.

↓

fine grain perlite - More strength as compared to Annealing.
- better dispersion of ferrite & cementite in pearlite.
- Improve Mechanical Properties.

air hardeable steel (Martensite formed
for avoiding → cooling rate should be slower than air
colling

Diffusion Annealing → chemical homoginity
↓ 2nd heat treatment

Normalizing
↓ refine grain size.

- Hypo eutactoid steel. low C steel
↓ normalizing
Strength & hardness both increases
↓
Machibility of low 'C' steel increases.

In the case of high 'C' steel we can do normalizing becase continicu network of cementit is not forming due to fast coolings as compared ~~by~~ to annealing.

↑ $Ac_3 + 20-30°C$ hyper
$A_1 + 20-30°C$ for eutactoid & hypereutactoid

↓ quenched → Tempering.
(Martensite) $Rc = 65$

fine perlitte $R_c = 45$

Coarse perlite $R_c = 20-30$

Factors Effecting Hardening:-

(i) Chemical composition:-

- Hardening Temperature

Plain 'C' steel %C determines hardening temp

Incase of Alloy steel, depends nature of alloying element as well as % alloying element.

- Austenite stabilize ; more retained austenite which do adversely effet strengthing.

- Carbide formers

Advantage

formation of complex carbide

~~rass~~ ↑ raises wear resistance

- If complex carbide ?
is present in a
matrix of Martensite

(ii) Shape and size of Specimen:

- Specimen consist of section of variable

- Complex shape, that rate of ~~heating~~ heating → slow

" " cooling should be such that complete hardening takes place.

(iii) Hardening cycle:- → shape & size

Includes heating rate, Holding temperature, holding time, cooling rate.

- heating rate slow ~~↑~~ → holding time reduces

- Faster " " → holding " increases.

Slow heating
Advantage: No thermal stresses, no internal stress, no surface oxidation / decarburization, No grain-coarsening.

Holding Temperature:- hig
hypereutectoid
$Ac_3 + 40\text{-}50°C$

hyper
$Acm + 40\text{-}50°C$

cooling rate:- . Cooling rate $\geq$ Critical cooling rate.

(iv) Homogenity & grain size of Austenite:-
(min)

(v) Quenching Medium:-
- Temp of medium
- " specific heat.
- Latent heat of vaporization
→ Thermal conductivity.
→ viscosity

(vi) Surface condition of Specimen:-
- presence of oil, dirt, foreign particles.
↓
adversely effect cooling rate.
↓
burn
↓
residue on the surface
↓
poor conductor of heat.

Solutions
proper cleaning is necessary

Hardening Method:-

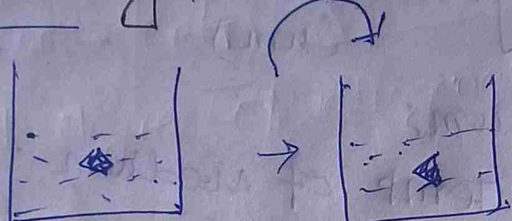
(I) direct quenching:-

quenching Media <=> water

results in lot of generation of internal Stresses. Oil can be used

—— Not Suitable for Large objective.

(II) Step quenching:- It Perform two step.

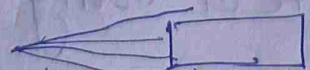


quenching media kept at a higher temp

kept at a lower temperature.

* internal stresses will be less compared to direct quenching

(III) Spray quenching:- is better than direct quenching.



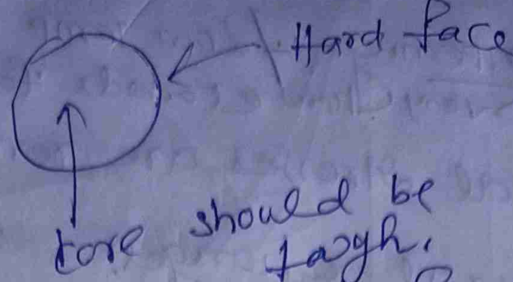
Sprey

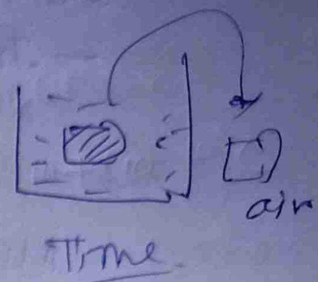
all the time fresh quenching Media is in contact with the Surface.

* No vapour Film formation takes place.

↳ use: Selective hardening.

(iv) Quenching with self tempering:-





- Suitable for large object.

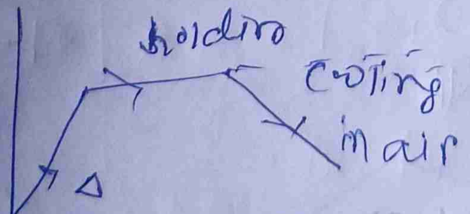
Martensite will be formes in the case,
In the core → Perlite (tough)

(v) Austempering:-

(vi) Martempering

Tempering → Follows hardening
↓
Martensite → hard
brittle
— Non. equilibrium phase.
toughness as well as strength
· hardness

— To stabilised Martensite.
→ To impart optimum properties



Structural changes during Tempering:-

First stage of Tempering:- / Low Temp Temper (upto ~~300°C~~ 250°C)

* Since $C\uparrow$ > very low e carbide form is very fine
- Internal stresses are remove to some extent

Structural changes:

Martensite → S
[supersaturated with 'c']
(C → diffusion out) → ppt in the form of carbide, but not cementite
ε-carbide {hcp}

Low carbon *Martensite
still → (BCT)
but degree of Tetragonality has decreased.

%C ↓

≃ 0.30%

$Fe_{2.4}C$ = $\%C = \frac{12}{56 \times 2.4} = 8.92\%$

High 'c' steel
Low alloy steel.
case hardened steel.
Cutting & Measuring test.

2nd Stage of Tempering / Medium Temperature Tempering. (350 – 500°C)

RA ⟶ Banite
differt from concentration of banite ferrite & cementite
(but not Lamellar)

ferrite + ε-carbid.

coil spring
Laminated sponge

hardness ↓
Toughness will increase.

3rd stage / High temperture Tempering (500–650°C)
Low 'c' Martensite, more and more carbon will diffuse out, 'fe' will also diffuse
α-ferrite + ε-carbide will undergo a re-arrangement as a result Fe_3C will form

α-ferrite + cementite
↓ hardness, toughness (↑)

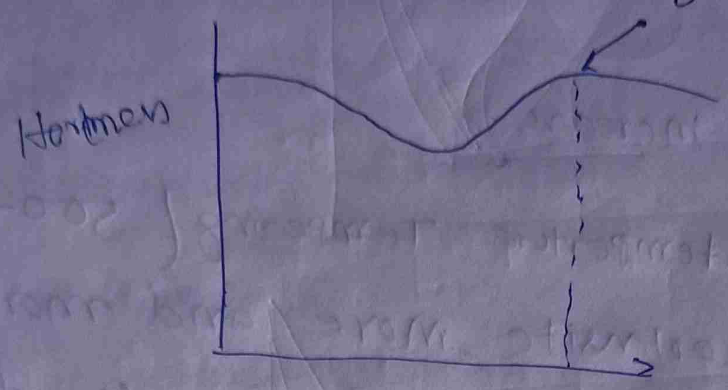
Medium c-steel
medium 'c' low alloy steel. → use connecting rod, Shaft, gears

* Effect of Alloying elements:
All alloying element raise softening temp

carbide
Non carbide
→ ferrite stabilizer,
→ austenite stabilizer
hardening is due to solid solution Strengthening

Carbide formers:

Secondary hardening:-



HSS
18/4/1 V4
Cr W V
C = 0.7%

Complex carbid
[Fe, Cr, W, W]$_x$ C

HSS - cutting tool
↳ cutting at high speed.
↳ hot (tip)
red → softening

red hardness.

Temper embrittlement:-

Slowly cooled
660°C
↓
400°C

drastic loss of toughness

remedies

A1 ↑. heating below. and then cool faster.

660° ↓ cool faster
400

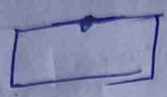
presence of
↳ P, $\boxed{As, Sb, Sn}$
stray element or tramp element.

↳ Avoid this element beyond its critical value
< 1

(ii) Mo, Ti, Zr can supress

(iii) Mn, ~~Zn~~, Si, Ni, Cr may also case embrittlement

Temper colours:-

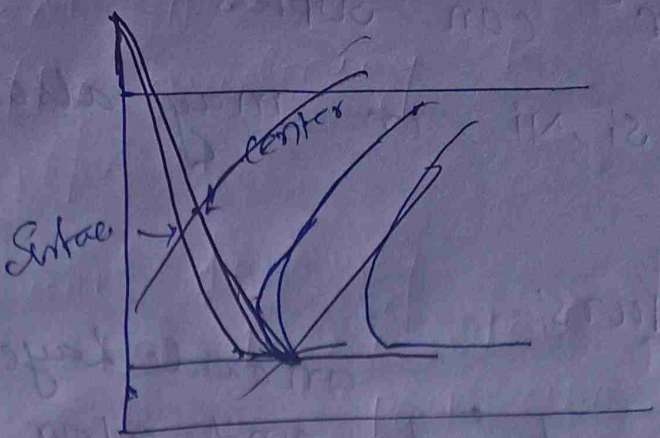


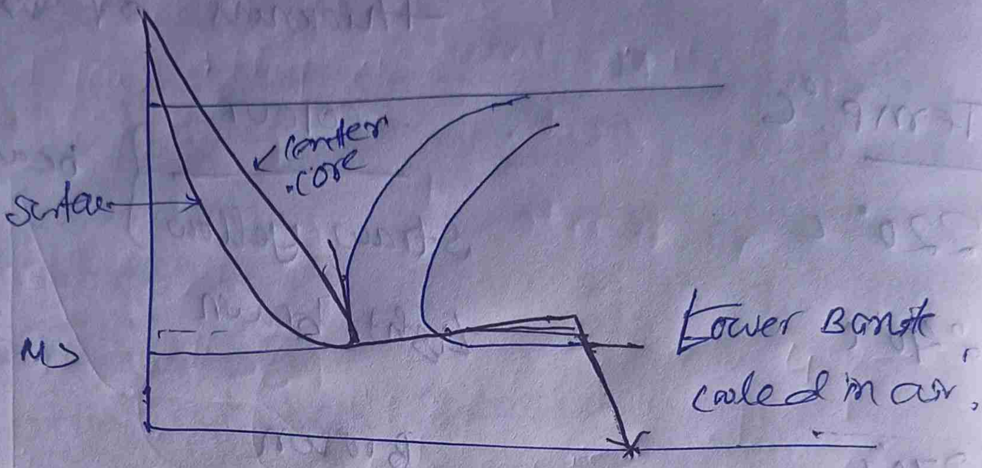
an oxide layer will form and colour changes with thickness of oxide film.

Temp, °C	colour
220 °C	Straw yellow
240 °C	Light brown
	Brown
270 °C	purple
285 °C	Dark blue
295 °C	Light blue
310 °C	Grey
325 °C	Grey-purple
350 °C	Grey-blue.
375 °C	Dull-grey.
400	

because at the temperat temp thickness of oxide film increase and colour change occurs

Austempering:-





cooling of core > CCR

200-400°c preferably in the lower banite region

Advantage: over conventional method
(Hardening + Tempering)

1. Less internal stresses
2. Greater ductility and Hardness level
3. superior imact and fatigue strength

Limitation :-

1. size limitation (Smaller size preferable)
2. Nose of the curve should be away from T axis,

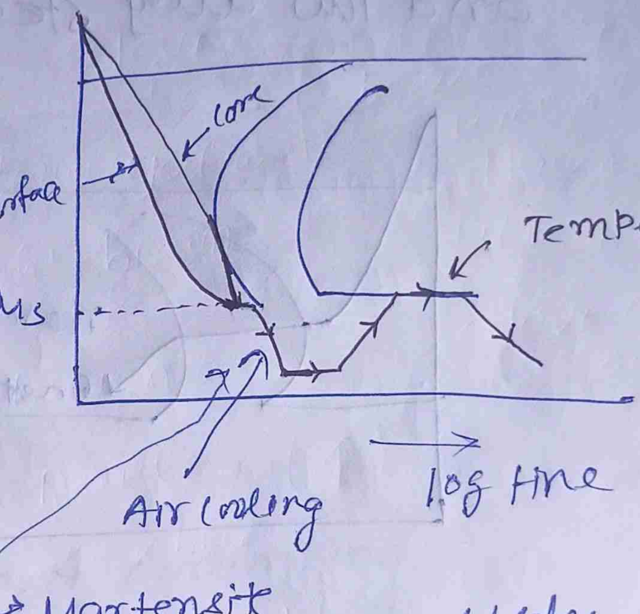
3. Tendency to Transform into pearlite should be less.

4. Austenite to Lower Banite transformation should be completed in quick time.

suitable for certain special grade of Low alloy steel.

Martempering!

180 - 250°C



→ alloying element increase hardenablity.

Subzero Treatment

Hardening

Martensite + RA (% C ↑) ↑

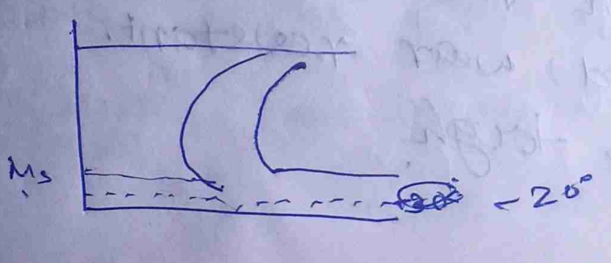
Micro structurally find → If RA > 20%

alloying conten ↑

↳ Austenite stabilizer

↑ RA

RA → poor Mechanical properties.



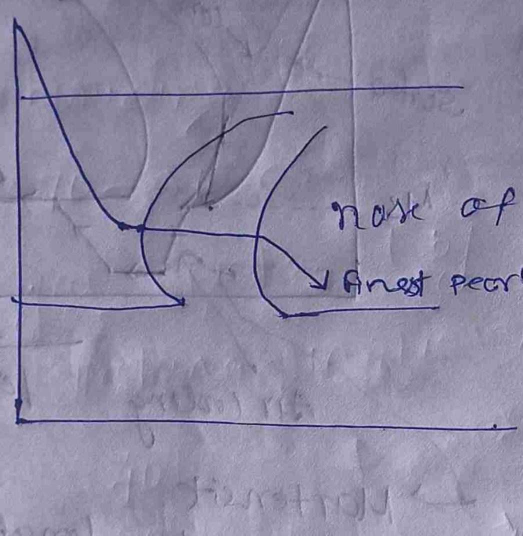
- 30°C to - 70°C

RA → Martensite.

Subzero Teratment should be carried out immidiatly after hardening

Patenting:- → wire drawing
→ for Low 'c' steel
↳ post anne-aling.

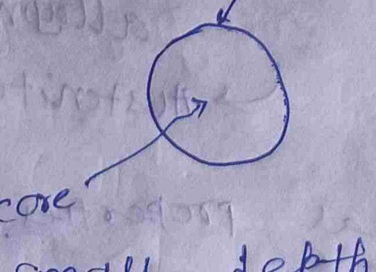
Patenting → Medium carbon steel & High 'c' steel, and low alloy steel is suitable



Microstructure : "Fine pearlite". Sometime upper banite.

bath is usually Molten Lead bath. (MP→ 327°C) or salt bath.

Case Hardening:-



ball bearing. Gears, cams, drill bits etc.

case is small depth from the surface.
case should be hard, wear resistant.
but core should be tough.

b. Liquid carburizing:

corrosive action on the part.
— hazard.

815°–900°C, NaCN / KCN

1-2 hrs

$BaCl_2$ → energiser

$2NaCN + BaCl_2 = Ba(CN)_2 + 2NaCl$

$Ba(CN)_2 + Fe = Fe(C) + BaCN_2$

Thin case 0.08 mm.

(c) Gas carburizing:-

870–970°C

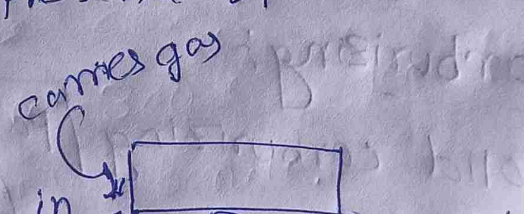
carrier gas, prepared by cracking of methane or propane in presence of air composition.

N_2 – 40

H_2 – 40

CO – 20

CO_2
Methane
O_2
water vapor
} traces.



Tubler Furnace.

Methane or propane.

$C_3H_8 \xrightarrow{} 2CH_4 + C$

$CH_4 + Fe \rightarrow Fe(C) + 2H_2$

diffusion 'C' from iron

$CH_4 + CO_2 = 2CO + 2H_2$

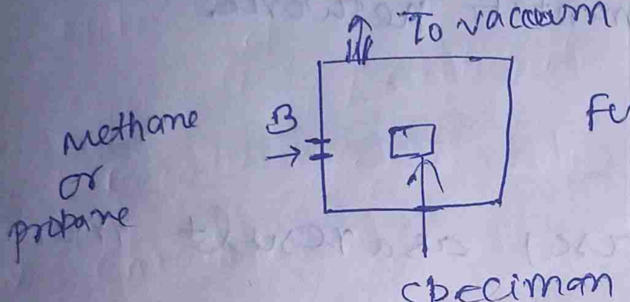
$2CO + Fe = Fe(C) + CO_2$

) vacuum carburizing:-

step 1 $\square$ - 'c' is made to be absorb on the surface.

925-1050°C

step-2 $\square$ 'c' atoms diffuse into the case.



furnace (i) at first gate B is closed

(ii) heating commences once the furnace is evacuated.

(iii) once it reaches Temp of carburizing Temp of ~~Temp of~~ than entry of Methane & proper are allowed. in a very brief time.

- once again furnace is evacuated
- Methan in contact with hot surface it cracks 'c' diposit over the surface. (step 1)
- diffusion take place in vacuum (step-2)

size limitation.

* vs gas carburizing 1: gas carburizing.
* ~~costly~~. not very costly.

0.15 to 0.25
0.7 to 1.09

Post carburizing heat treatment:

- Speciman is held at a very high temp for a very long time there will be grain coarsening

→ continius network of cementite will form in the case which is brittle

→ Refine of the grain size

→ — brake the cementite network.

Normalizeing for core.

↓

qenching → (for case) as a result martensite will form in the case.

(III) Tempering to a temp 300°c to convert retained austenite into banite.

Nitriding:- Al, Cr, W, V, Mo

Step-I hardening (quench from 930°C)

Step-II Tempering, 650°C ⟶ Banite.

Step-III Machining, grinding.

Step-4, The portion not to be nitreded is coated with Tin.

$$2\,NH_3 \xrightarrow{550^\circ c} 2\,[N]_{Fe} + 3H_2$$

900-1100 VHN
20-100 hrs
0.5 mm → 100 hrs.

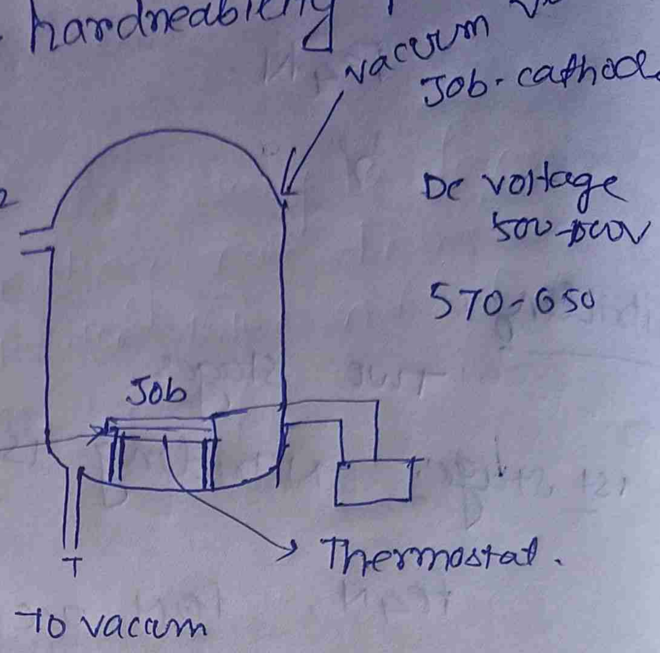
C – 0.8 – 1.2 %.

N → 0.3 % → hardneability ↑

Plasma Nitride:-

N_2, H_2 → Ionised

Bombartment 'N' ion on the Job



DC voltage 500-800V

570-650

→ Job will headt up

→ Diffusion of 'N' on the Job surfac.

→ Secondary electron from the Job surface will be removed i.e it does cleaning of surface

Adv: Since 'N' diffusion is controlled, negligible amount of white layer forms.

→ Complex Shape can be Nitrided.

→ Excellent dimensional stability "

→ better fatigue Strength.

Limitation:-

Very costly

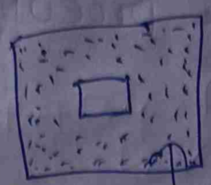
→ Slow growth of case.

→ quite popular

Name:- Kalyanmoy Mandal, Page:-
Roll: 247/18

Pack/gears,

Boronizing:-



resistant boxes

granules of Boron carbide
9~~8~~00 - 1000°C

Disadv

1500 — 2100 VHN

Fe_2B, FeB
Near layer, outer layer.

Both brittle (that not desirable).

High Temp, long Time, high alloy Stee

Uses: Extrusion dies,
- wire drawing
- Forging dies
→ ingot mold.

Chromizing:-

Hard chromizing:- %C > 0.35%
Case" Chromium Carbide in the case ↑ hardness
60% Cr (ferro chrome)
0.2% NH_4I
≈ 40% Kaolin powder

Soft Chromizing C < 0.35%
Since %C is low ~~Cr~~ chromium carbide does not form,
'Cr' could be as high, 35% in the case.

Name:- Kalyanmoy Mondal

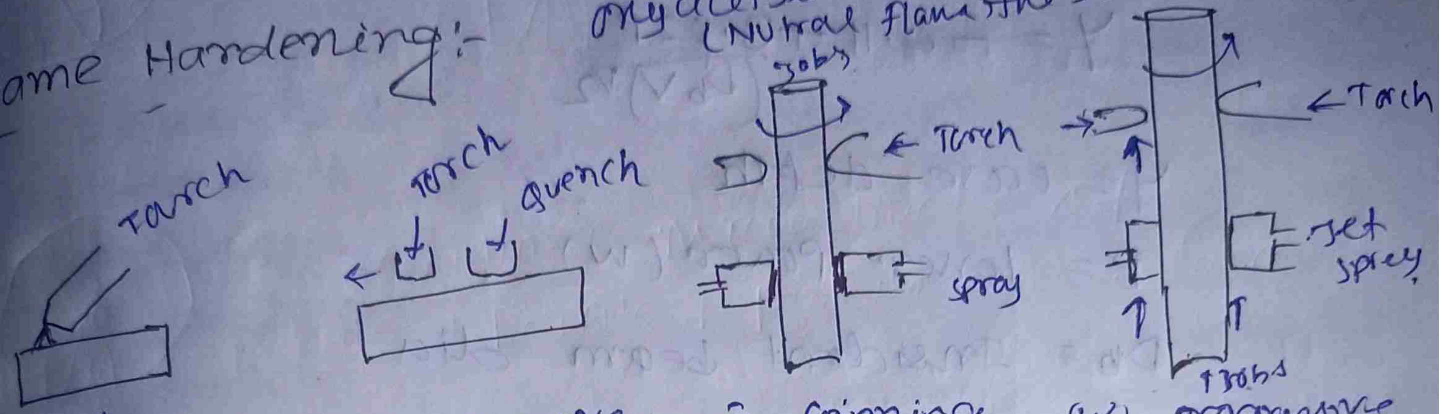
Page:-

Roll: 247/18

→ highly resistant to corrosion

→ highly " " oxidation.

Flame Hardening:- Oxyacetylene torch is used to heat the job or wp. (Nutral flame or slightly reducing flame)



Job

i) Manual or stationary.

ii) progressive

iii) Spinning

(iv) progressive spinning

Heating

↓

quenching

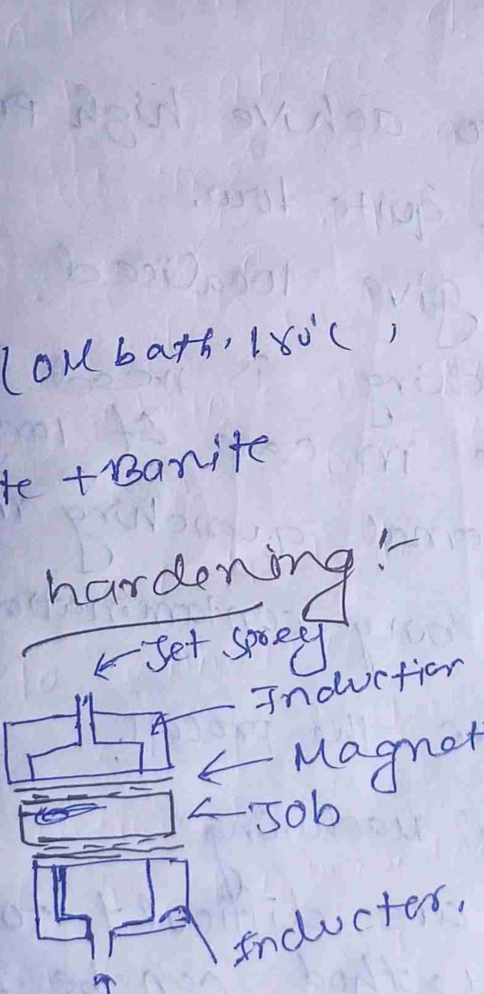
↓

Tempering (Oil bath, 180°C)

↓

Martensite + Banite

Induction hardening:-



Larger Jobs

Skin effect.

Case depth $\propto \frac{1}{\sqrt{f}}$

higher frequency

Laser hardening:-

heat devlop by fousing is very high.
Job is heated with a defocused beam

Cape depth:

$$Y = -0.11 + \frac{3.02P}{(D_b V)^{1/2}}$$

Y = case depth.
P = lesser power (W)
D_b = Insident beam dia
V = traverse speed.

Advantge;

(i) It is possible to achive high production rate.
(ii) Input distortion is quite low.
(iii) It is possible to give localised treatment.
(iv) No extrernal quenching is need since self quenching takes place in case of larger Job but for smaller Job external quenching may be neede
(v) There is hardly any contamination.
(vi) Better controlled over the process.
(vii) No need of final machining
(viii) Those area which are difficult to be treat by conventional Method can be easily treated by this technique.

comparison b/w lesser hardening & conventional hardening

(i) It is possible to harden low 'C' steel with ease, but can't do in convenction.

(ii) Level of hardness achive by lesar hardening is higher than conventional hardening.

(iii) ~~f~~ leser hardening is not suitable for those alloy steel which need Larger soaking time, Larger soaking time is needed in case of those steel containing spheroidal carbide or cast iron rich in graphite instead of pearlite.

case depth → Measurement

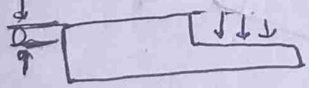
⇒ (i) Hardness Method.

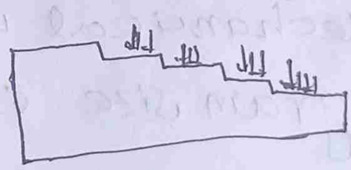
(ii) Chemical "

(iii) Macrostructure "

(iv) Microstructure "

(i) Hardness Method:-



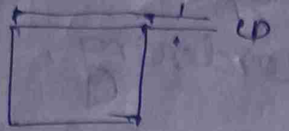


(i) cross-section Method (for lighter)

(ii) Taper grand Method (Medium section)

(iii) Step grand metho (Havier section)

Chemical Method:
(o- where there is change in chemical compo-sition)



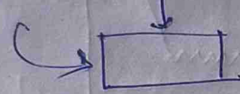
smaller chips are taken out by turning → chemical analysis

(1) If chemical composition → uniform till a certain depth.

3. Macrostructure Method:

hardened surface

polish



X 20 Observe

(4) Microstructure method: high Magnification.

Increasing demand for high strength steel.

- By alloying
→ By Mechanical working
→ By grain size control.
→ By heat treatment.

Thermomechanical Treatment

Just any combination of Mechanical working and heattreatment may not give good results

Essential condition:- Mechanical working must affect the phase Transformation.

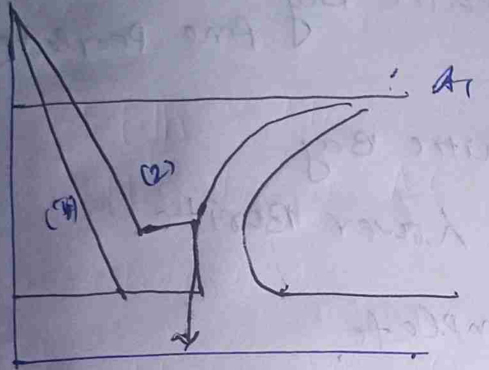
result in the creation of voids, vacancies, dislocation. Subgrain boundary etc. Stacking faults etc.

ready Nucleation site
rate of diffusion will increases
- change in kinetics of Phase Transformation.
→ Morphology of Microstructure will change which result

classification of Thermomechanical Treatment

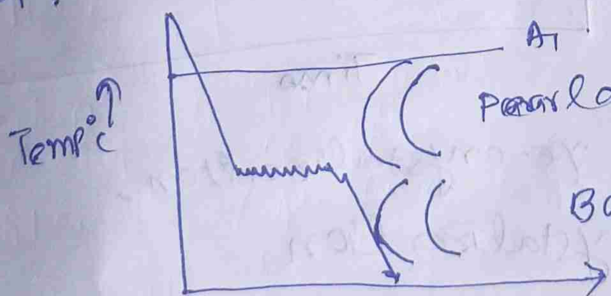
↓ Recrystallization
deformation temp. (20%-30%) above or below

recrystallization may or maynot temperature take place
(i) Supercritical TMT (Above Ac_3)
(ii) Intercritical TMT [Ac_3 & A_1 (hypo)]
(iii) Subcritical TMT
↳ below T_1



1. HT, TMT → Low in strength but greater in ductility
2. LT, TMC
↳ high in strength, lower in ductility.

Heavy deformation is carried out.



(i) Gap b/w Pearlitic bay & Austenic bay should be large
(ii) Incubation Period should be large.

→ Extant of deformation.
→ Temp → (should fall in the ga
→ rate of deformation.

Nature of alloying Elements.

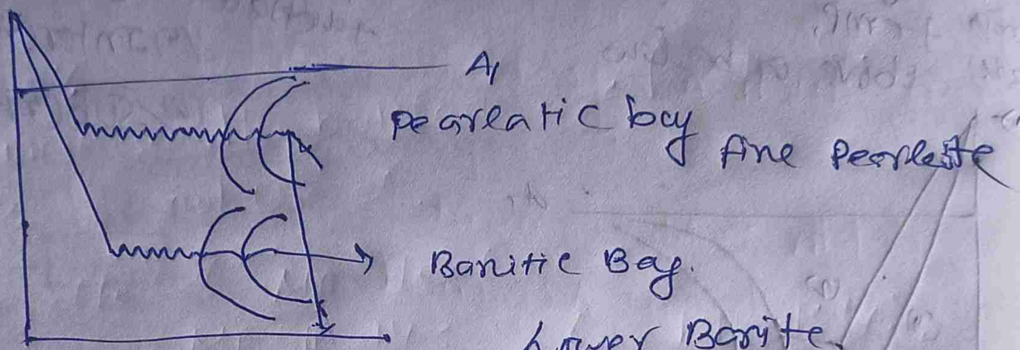
- Some alloying elements raise stacking fault energy (Ni)
- other alloying element lower stacking fault energy increase in strength ↑

↳ Increase rate of work hardening.

hence strength increases.

Isoforming:

deformation is carried out at const. temp



till the transformation is complete.

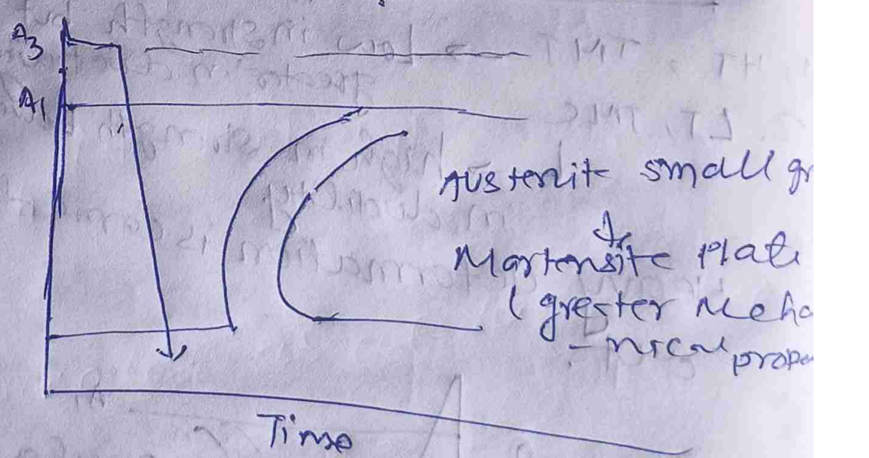
Hot cold Rolling:-

↓

deformation is carried out above A_3 temp ↑

Cold Rolling:

deformation is carried out in such a manner that there is minimum re-crystalization.



To further Suppress re-crystalization

V, Ti, Nb → tend to redard re-crystalization.

Marstraing:-

Above A_3 ↑ Austenite

↓ quenced.

Martensite (brittle)

As quenched Martenside is Tempered, Tempered Martensite is bit ductile → so deformed,

deformed Martensite ⟶ Retempered (Lower than pre. tempering temp)

After re-tempering ε carbide formed in 1st stage of tempering, dissolves back

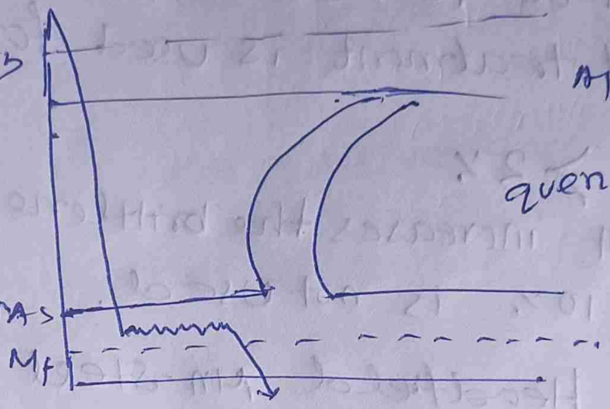
→ dissolve carbon anchors the dislocation, thus raising the strength.

Cryoforming :-

⇓

Applicable to those steel which cannot be strengthened by cold working.

due to higher rate of work hardening.



quenched below M_s

⇓

Martensite will form

part of retained austenite is transformed into Martensite

Transformation Foll

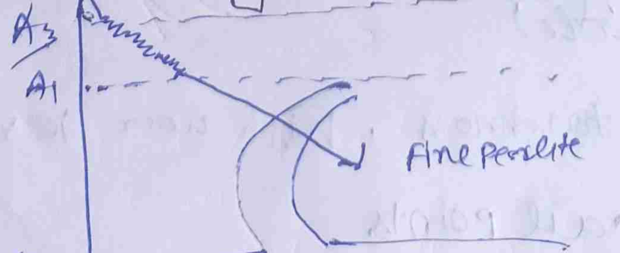
Zerolling

better Mechanical properite. } deformation + crying sund ~~some~~

some RA is not transfored ⟶ which transform in Martensite later during service in resulting

Thermomechanical annealing :-

Mechanical working + Annealing



process involves heating above A_3 than Mechanical working start just below A_3 and it continues just below A_1 followed by slow cooling in so.

ferrite + cementenite (globules) → Fine.

↓

raises Machibality

Spherodizing Annealing we get same micro-structure (highly time consuming)

Heat treatment

HSLA → Microalloy < 0.5%

⇒ alter, the heat treatment behavior of steel.

Mn-steel:-

Mn 1.60 to 1.90 %, in rolled condition without heat treatment is used for structural purpose.

Mn > 2 %

→ It increases the brittleness of steel.

2 – 10 % is not used.

exception. Headfield Mn-steel

$Mn = 11 - 14\%$ $C = 1.1 - 1.4\%$

$\frac{Mn}{C} = \frac{10}{1} = 10:1$

1000°C

↑ ↓ (No. Tempering)

water quench

Recomonded below 300°c

Tempering is not recomonded as at higher temp carbide may ppt.

eg:- crushing plate of stone (stone-crusher) (Face plate)

It posses:-

Strength, toughness, high wear resistance, &

Used' rail points

Silicon Steel :

- It raises elastic properties.

→ It improves electrical & Magnetic properties.

→ Used as : cores of electric Motors, transformers.

Si – 3-4%. If Si > 4%, it causes brittleness to steel

C = 0.5%.

addition of Si ↑ coercive force (Hc) increases

Low eddy current flux due to high electrical resistivity.

Annealing & rolling — coarse grain structure, oriented grains, oriented grain steel.

↑ 1100–1200°C

↓

slow cooling

2% Si, 1.1% Mn, C → 0.50 – 0.70 → spring steel

because that can used for coil spring, leaf spring.

↑ 840–930°C

↓

oil quench

↑ 400–550°C

Tempering.

Heat Treatment

Maraging steel:-

Martensite + Ageing → with passing time

room temp Ageing → Natural Ageing.

eleveted temp → Artificial Ageing.

Fe + Ni

C - impurity

0.03%

↓

quenched

Martensite

(low strength but ductility is high.

Ageing ↓ ppt → presipitation of intermettallic compounds

Ni - 18%

Mo → 3%

Co → 8.5%

Ti → 0.2

Al = 0.1 %

Hardening Temp

820°C, 1hr.

Ageing

480°C, 3hrs

Heat resisting steel:-

↓

application at eleveted temp.

upto 300°C.

(i) Plaine C-steel grades.

(ii) Low alloy steel grade

(iii) High alloy steel grades

(i)

Plane C-steel grade - pearlatic grad.

% C 0.10 — 0.20 920 – 950°C → oil quency → 700 – 740°C

% Cre 0.70 – 1.00

MO 0.40 – 0.50.

(ii) . Martensite grade.

C → 0.15% (max) 950 – 980°C 680 – 730

Cr : 5 – 6.5%.

MO = 0.45 → 0.50%

Low alloy steel,

iii) High alloy steel grades:

% C 0.1 – 0.2 1030 – 1060°C oil qanch 650 – 700

% Cr 10 – 12%

% MO 0.6 – 0.8%

% V 0.25 – 0.40

Heat Treatment of High speed steel:-
⇓ cutting tool
Very high speed

- Red hardness (hardness is maintained even if it is red hot)
→ high wear resistance.

The Most common HSS cutting tool : 18 | 4 | 1
W Cr V

C = 0.7 – 1.4%. C = 0.7%.

W = very costly & scarce.
→ W is substitute parly by MO

Mo based HSS

- No substitute Mo than it is called W based HSS

Co is added

↳ decreses hardeability

- raises cutting ability of tool.

Application:

Heavy cutting Tool

Milling cutters.

reamers

deep hole drills

blanking dies

- Hot forming dies.

Heat Treatment:

For regular shape and small size and for complex

For regular shape & small size	For complex shape & Large size
1. heating is carried out in two stage	1. heating is carried out in three stage.

Holding Temp = 1150°C - 1350°C

- Scaling (oxidation)
- de-carburization
- grain coarsening