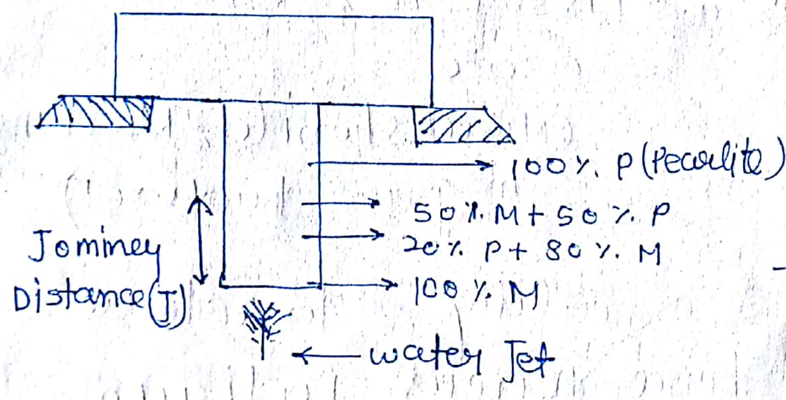
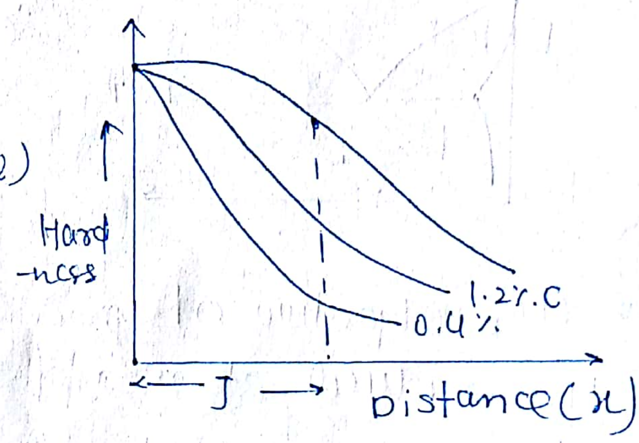
Hardenability :- Ease of martensite Formation

Jominey and Quench Test :-

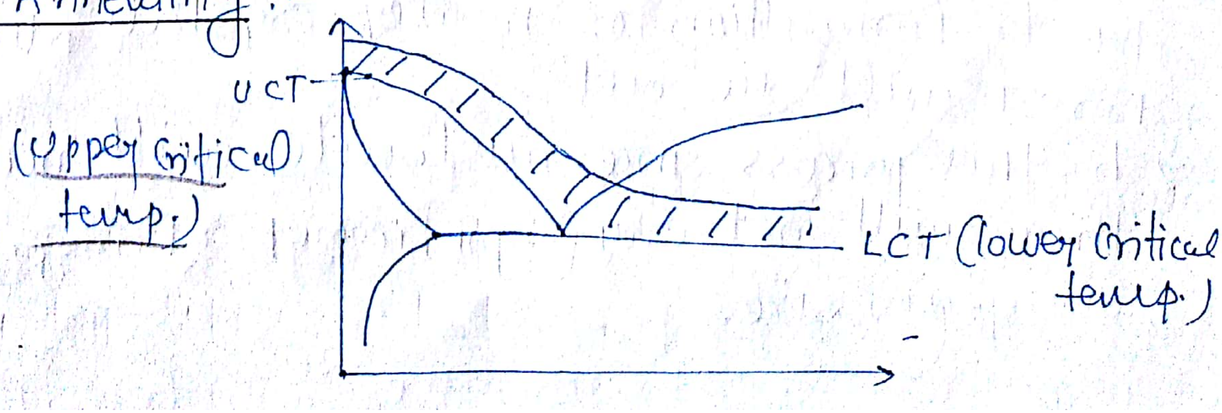


Hardenability Curve



Annealing :- Heat upto a temp. in furnace then cool slowly

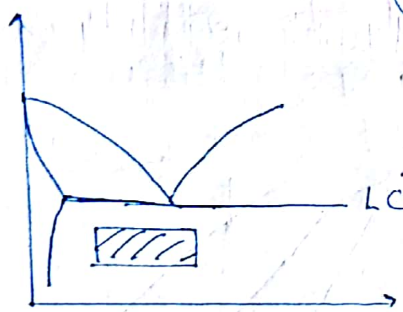
(a) Full Annealing :-



→ Objective of Full Annealing is to reduce hardness or brittleness and to increase ductility and toughness.

→ Hypoeutectoid steel are heated 50°C above UCT and hypereutectoid steel 50°C above lower critical temp (LCT). After keeping sample at this temp for some time it is cooled slowly in furnace. After full annealing resultant microstructure is coarse pearlite.

(b) Process Annealing:–



0.5 Tm

⇒ 0.5 (1535 + 273) − 273

= 630°C

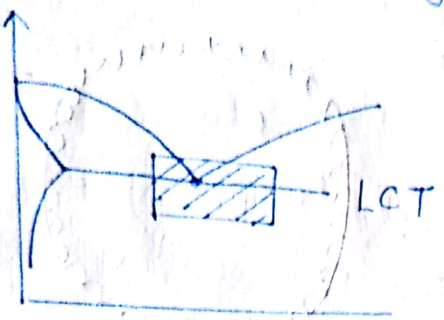
(No austenite, No chang in grain structure)

→ The objective of process annealing is to relieve the residual stress and hence increas fatigue strength of material

→ low c steels are heated to temp. of 630°C (Recrystallisation temp) i.e. slightly less than LCT and then cooled slowly in furnace. Due to formation of newer crystals dislocation forest will die out

→ In this process since austenite will out from, there will not any significant change in grain size.

© Spherodize Annealing (isothermal ~~annealing~~)

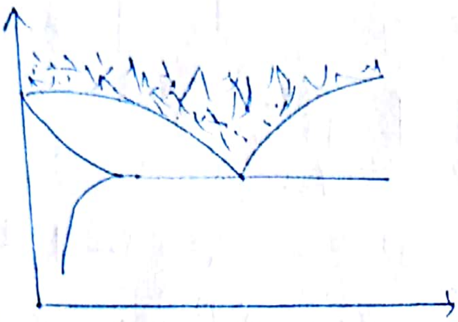


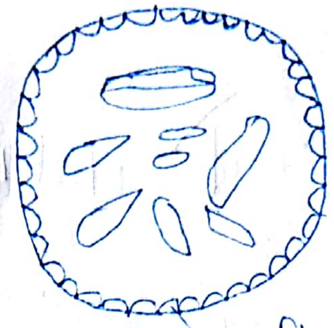
- The objective of spherodize annealing is to increase machinability of medium and high C steels.
- These material heated close to LCT and then cooled extremely slowly in furnace
- Machinability is improved by formation of spheroids. (20°C/hr)

ⓓ Diffusion Annealing (Homogenizing)

- During fabrication of some structure if welding process is used at no. of places this changes the chemistry of material. Diffusion annealing is performed to make material homogenous in chemical composition
- Material is heated to approximately 1150°C and then cooled slowly in furnace.
- Higher temp. are selected to enable diffusion phenomena more and more

Normalizing

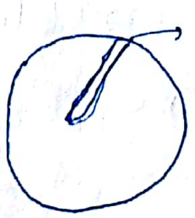




⇒ Hard Surface tough core

Steel sample are heated to a temp. at which austenite is in the stable condn. from that temp. It is ~~in the stable condn~~ air quenched. Since surface will experince Faster cooling rate So we get fine grain structure but towards the core cooling rates will decrease so structure will be coarser and coarser. Due to this microstructure material will have hard surface and tough core i.e. microstructure that can be used directly in any engg application that's why normalizing is considered as Final heat treatment process. Also hardening and tempering are meant only for selected material

1) Hardening :-



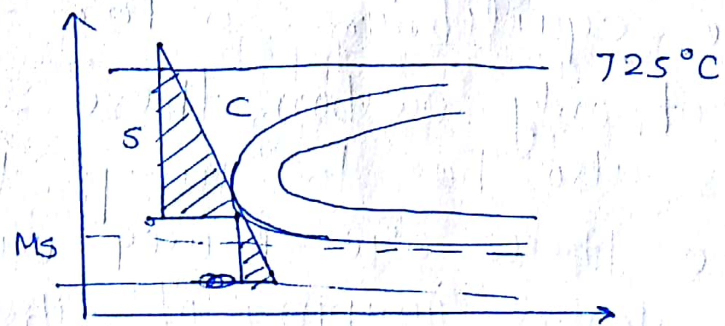
γ - FCC ρ ↑
M - BCT ρ ↓

Steel sample are heated to a temp at which austenite is in stable condn from that temp. It is cooled at a rate ≥ Critical Cooling rate to produce martensite in microstructure. objective of hardening is to produce martensite structure.

* when a sample of steel is quenched into some medium, surface and core will experince different cooling rate. since surface experince Faster cooling rate, immidiately it will convert into martensite and it becomes rigid. But the core is still having austenite microstructure since austenite is having FCC structure so it's density will be high. After some time period when core converts into M, Material is going towards lower density from higher density so centre will expand. this produces cracks on surface so cracks during quenching are due to density difference.

② Martempering :-

S - surface
C - core

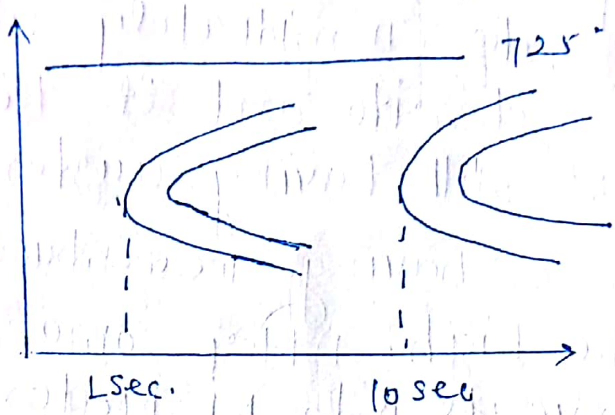


Austenite sample is quenched into a hot bath maintained at a temp. below the nose and above M_s. Sample is kept at this temp. for certain period of time so that temp. b/w surface and core becomes uniform. sample is then taken out from hot bath and quenched into a cold bath maintained at room temp. Martempering is decrease temp.

gradient and ~~have~~ hence density gradient in sample
It decreases possibility of cracks but doesn't completely eliminate it
(stepped quencing)

③ Alloying

17.5 °C/sec



If steel is added with some impurity atom so that it occupies substitutional site, entire TTT diagram shifted towards right, substitutional impurities creates strain field in material, due to which carbon is not able to diffuse from on interstitial site to another to achieve equilibrium. So for the equm to happen not only carbon, these substitution impurities also has to jump to some vacance site. Since there are fewer vacancy sites in the material jumping of substitutional impurity takes time. This increase incubation period, Some time even the air quencing may produce martensite.

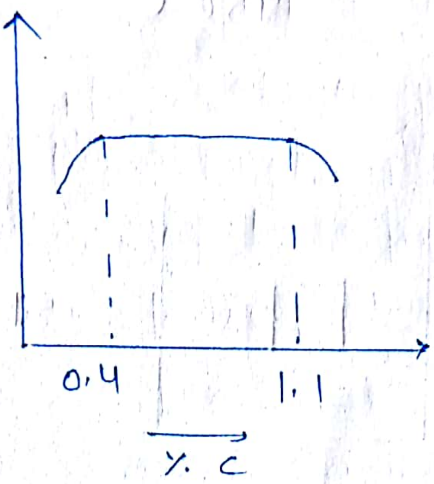
Quenching Mediums:-

① **Water**:- less heat transfer due to vapour formation

② **Salt bath**:- (Brine) fastest cooling but non uniform cooling

③ **Oil bath**:- critical cooling rate is decrease so used for alloy steeps only. uniform and slow cooling.

$\left(\frac{y-x}{x}\right)\times 100$



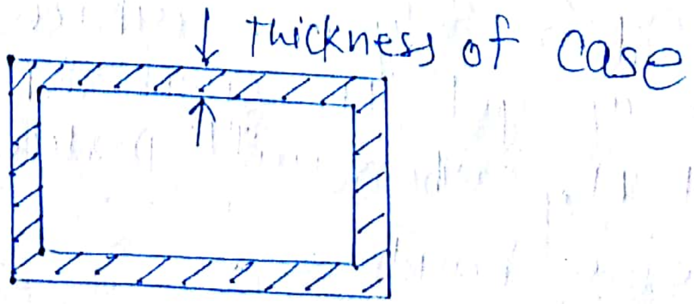
x - hardness before heat treatment

y → hardness after heat treatment

⇒ only eutectoid composition produce 100% martensite. The moment we deviate from eutectoid composition there will be proeutectoid phase and this phase doesn't contribute to formation of martensite.
So low c steels and very high c steel are not suitable for heat treatment But in most of engg application we use mild steel and their strength is increase by case hardening

Case hardening:-

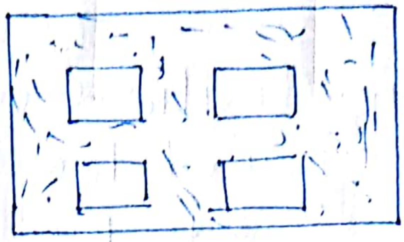
mild steel



① Carburizing

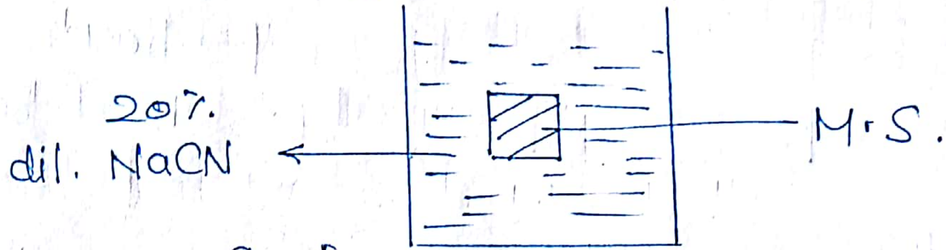
(a) Pack carburizing

carburizing
50% charcol
+
$BaCO_3$
+
$CaCO_3$



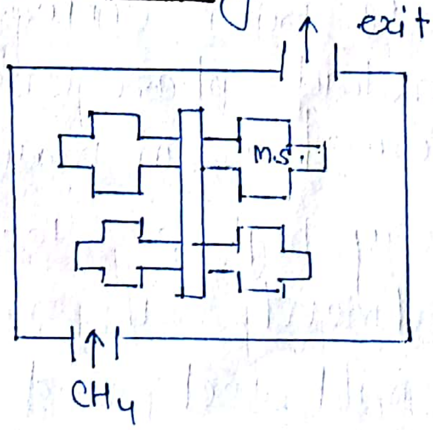
950°C

(b) Liquid carburizing



950°C

(c) Gas Carburizing



950°C

By diffusing carbon into the surface of m.s. specimen, % of C approaches towards eutectoid composition only on surface and upon quenching we may get M. Even if we are not able to get M, carbon will produce surface, this increase hardness.

Although pack carburizing is cheap and easy to perform but the process takes lot of time and thickness of case is non uniform. Liquid carburizing produces very good quality cases but bath is not only expensive but also highly poisonous.
Gas carburizing process can be automated and thickness of case can be controlled by time period during which gas flows into the container.

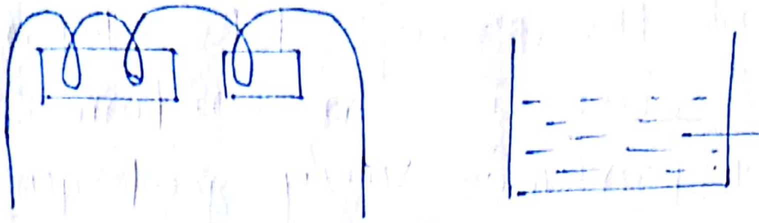
② Nitriding :- At 650°c Nitrogen will diffuse into MS speciemen from NH_3. Since nitride case will be harder and brittle, sometimes further heat treatment is required after nitriding

③ Cyaniding :-

In this process 30% NaCN + NaCl + Na_2NO_3 liquid soln is used at 850°c both carbon, Nitrogen will diffuse into carbon, Nitrogen will diffuse into m.s. speciemen. So properties will be in b/w carburizing and Nitriding

N > CN > C

④ Induction Hardening :-



Thickness of case $t = 500\sqrt{\frac{\rho}{\mu f}}$

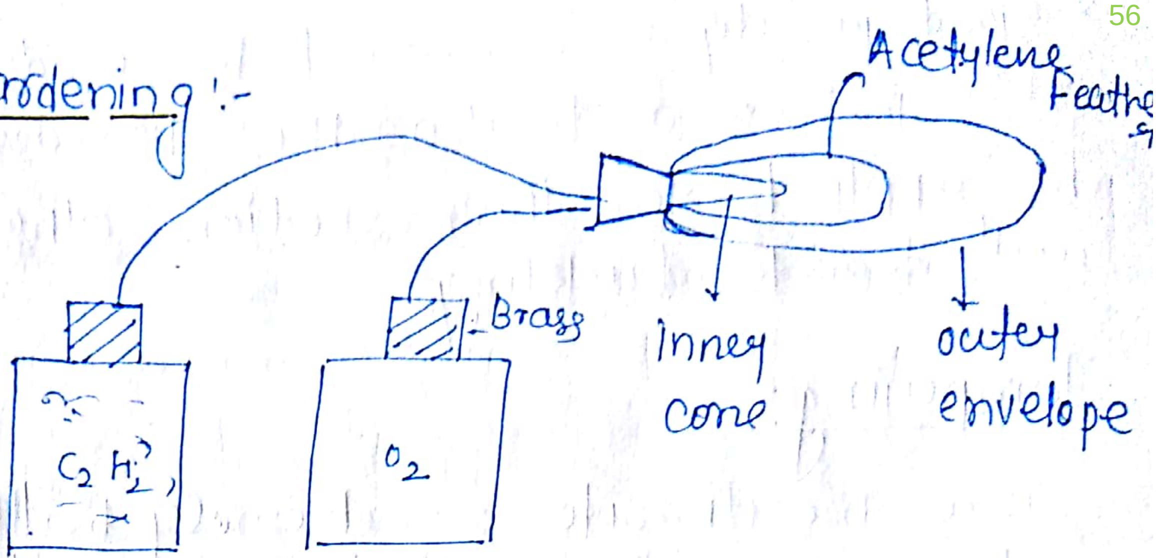
ρ - electrical resistivity
μ - magnetic permeability
f - frequency

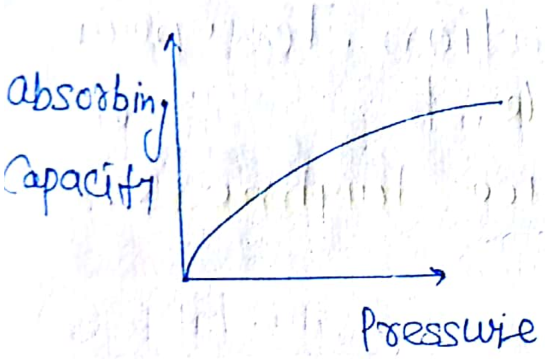
* Crank shaf, connecting rods.

→ It is the fastest method of case hardening the specimen and connecting rods are case hardened by this technique material should be alloy steel with % of c in medium carbon steel range

→ Samples are passed through induction coil and due to development of eddy current on surface heat will develope The advantage of induction hardening is that heat can be localised samples can be immidiately quenched into an oil bath maintained at room temp. This produces a thin layer of M over specimen.

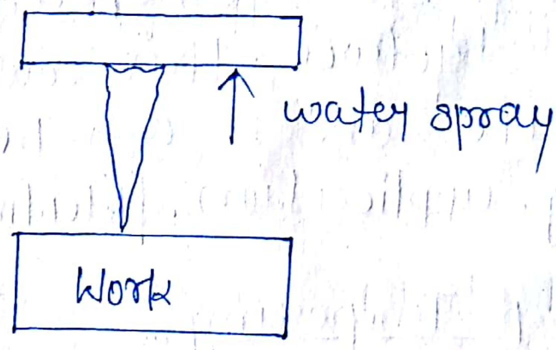
⑤ Flame hardening :-





- carburizing
- Neutral 3150°
- oxidizing 3480°

⇒ cam shaft (Medium C steel)



Cam shaft are case hardened by Flame hardening By this technique, medium 'c' steel material are heated by oxidizing flame and then immidiately quenched with water. This produce a thin layer of M over specimen

→ Sometimes low 'c' steel are also case hardened but in that case we will be using carburizing flame.

→ Good quality case can not be produced, by this process and also this process can not be applied to thin section otherwise it will lead to buckling

Tempering:-

Since martensite is extremely brittle in nature so this microstructure will not use directly in any engg application. Tempering is performed to reduce brittle of material and also to introduce toughness.

(a) High temprature tempering:-

Martensite is heated to around 500-650°c and then cooled slowly in furnace. Submicroscopic cementite combines together and forms a microscopic structure. This coarse structure is called 'sorbite' and it can be used directly in any engg. application. [Weidmanstann structure]

(b) Medium temp. Tempering:-

Since temp. of temping is low, so cementite will appear on a finer level and this micro-structure is called 'Troostite' (350-500°c)

→ used in production of springs

(c) Low Temp. Tempering:- Since temp. is very low, so diffusion is not expected and only thermal stresses during quenching can be released. The process is used in manufacturing of agricultral tools and metallurgial equipment (250°c)