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HEAT TREATMENT

- To increase the hardness, wear & abrasion resistance and machinability.
- To re-soften steels after its hardened by heat-treatment.
- To adjust the mechanical, physical & chemical properties.
- To remove trapped gases.
- To change grain size.
- To improve machinability.
- To modify magnetic and electrical properties.
- To stabilise steels.
- To relieve internal stresses set up during cold-working, casting, welding and hot-working operations.

CLASSIFICATION OF HEAT TREATMENT PROCESS.

GROUP-I : First order annealing / Recrystallisation annealing.

GROUP II : Second order annealing / full annealing.

GROUP III : Hardening,

GROUP IV : Tempering, Normalising.

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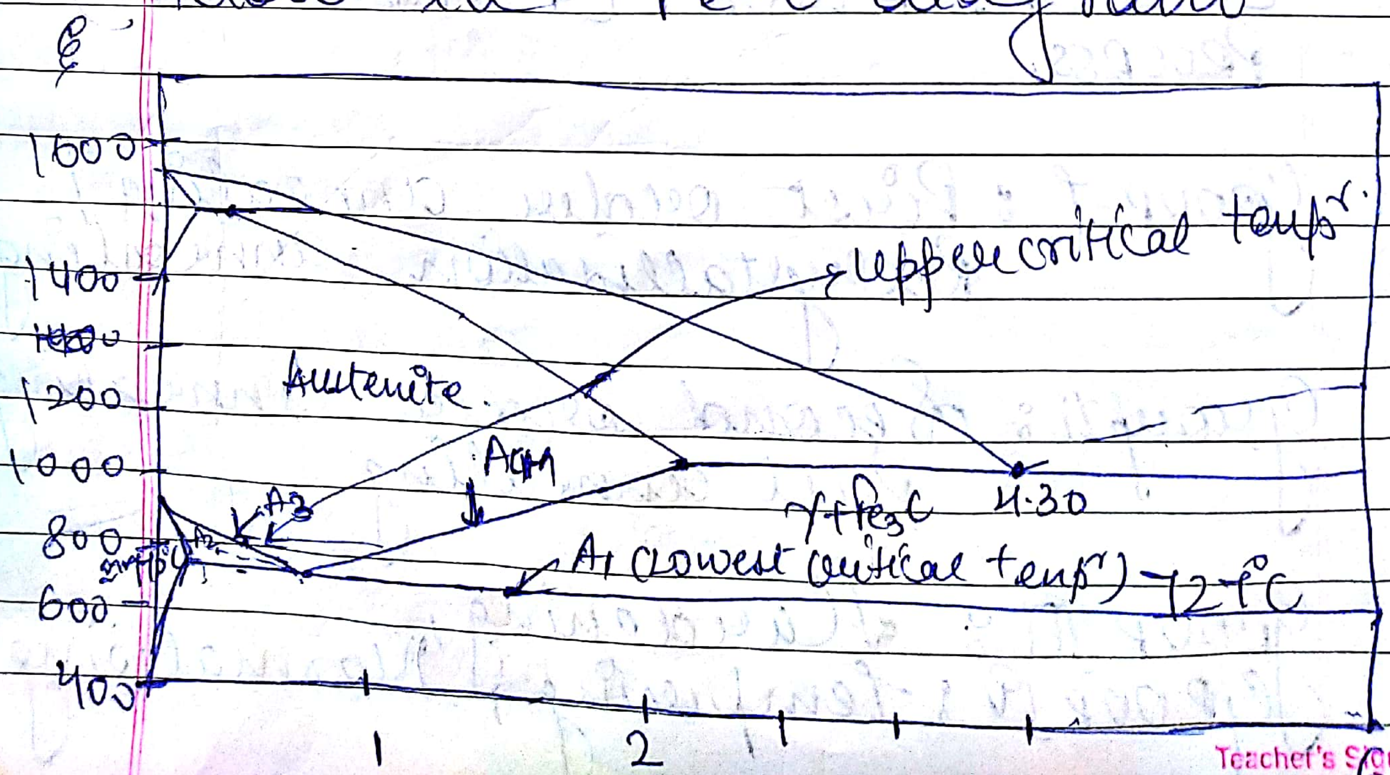
→ There are many different heat treatment process.
→ Some of the important one's are:-
Stress Relieving
Annealing
→ Full annealing
→ Partial annealing
→ Sub-critical annealing
→ Isothermal annealing
→ Diffusion annealing
→ Process annealing
→ Recrystallisation annealing
Normalising
Spheroidising
Hardening
Austempering
Martempering
Sub zero treatment.

Now in Fe-C diagram



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STRESS RELIEVING

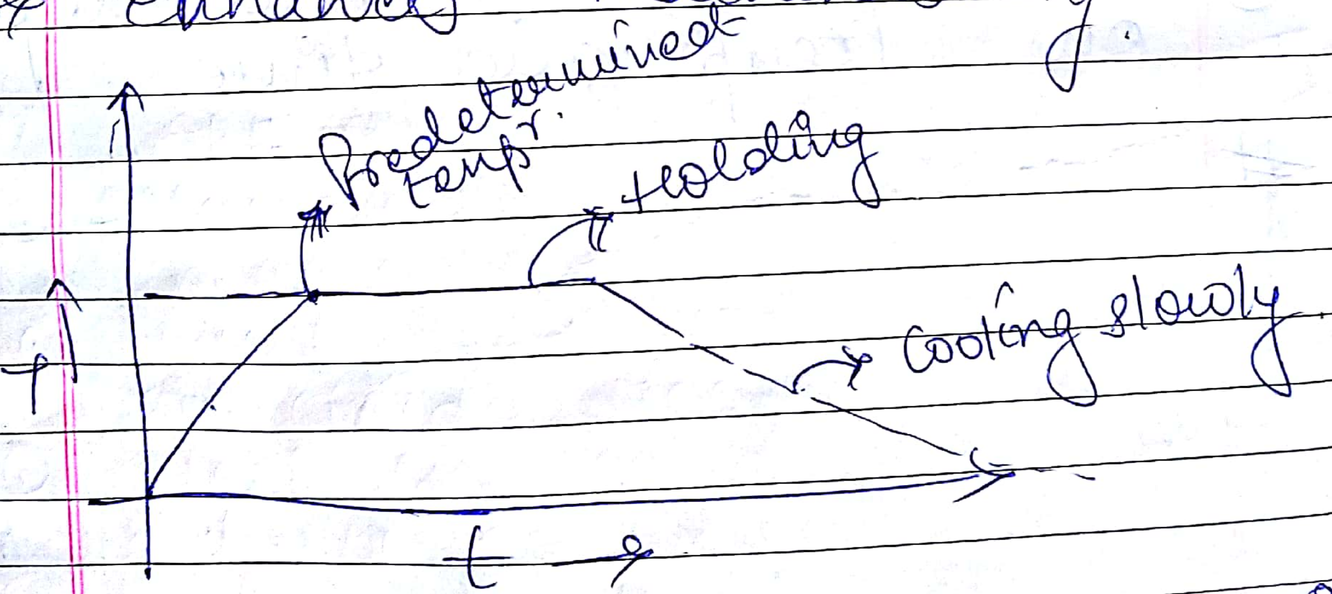
- Used to remove internal stress.
- Present of internal stress leads to:-
  → Failure of undue corrosive environment by stress corrosion cracking.
  → Fatigue strength reduces.
  → Dimensional stability decreases.
- No microstructural changes.
- Involves heating to a tempr below lower critical tempr and holding for sufficiently long time.
- Uniform heating, else internal stress develop during.
- Extent of stress relieved depend on temp and time.

ANNEALING

Steps involved
→ Heating to a predetermined temp^r.
→ Holding at that temp^r for certain time.
→ Cooling very slowly.

Temperature is decided by:
→ The composition
→ Desired property.

Purpose.
→ Relieving internal stress
→ Improved ductility and toughness
→ Refine grain.
→ Enhance machinability.



Types of annealing depending on temp^r of treatment.
1. Full annealing:

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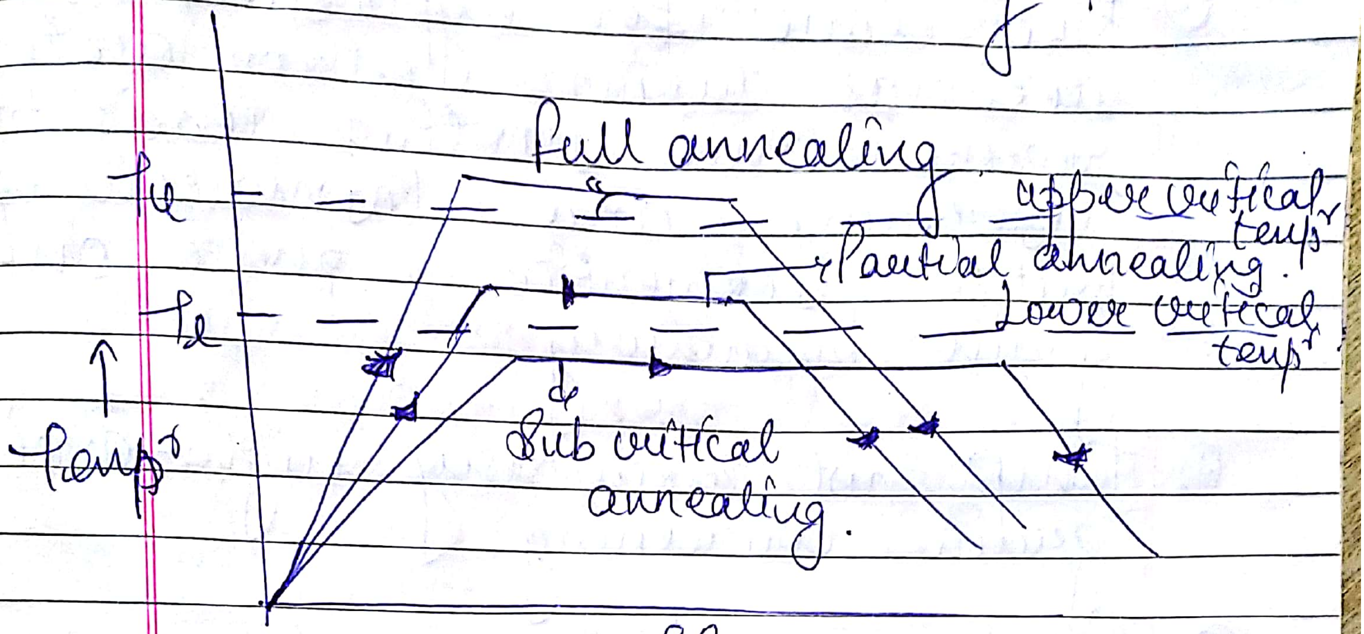
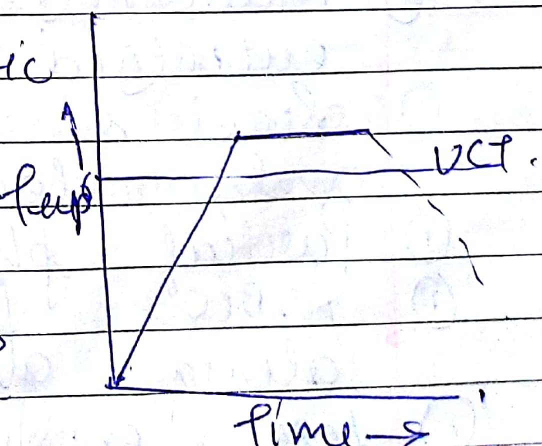
2. Partial annealing
3. Sub critical annealing



Type of annealing depending on purpose:-
① Diffusion annealing.
② Process annealing
③ Recrystallization annealing

1) FULL ANNEALING.

① Heating to austenitic region followed by slow cooling.



① 30°C - 50°C above A_3 for hypoeutectoid steel

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- 30°C to 50°C above A_1 for eutectoid steel.
- Not done for hypereutectoid steel as taking it to austenitic region and cooling leads to coarsening and formation of brittle cementite phase on grain boundary.
- Temp^r not taken very high - avoid grain coarsening.
- Improves ductility, toughness and machinability of steel.
- Lamellar pearlite formed, inter-lamellar spacing depends on temp^r and cooling rate.
- Long annealing cycle.

2) PARTIAL ANNEALING
- Alternatively called intercritical annealing.
- Mainly carried out for hyper-eutectoid steel.
- Steel is heated b/w A_1 and A_{cm} and cooled slowly.
- Partial phase transformation
- Avoids formation of cementite along grain boundary.
- Less expensive process.

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- Hypoeutectoid steel can be subjected to improve machinability

3. SUBCRITICAL ANNEALING

- Carried out below A_1 temp.
- No phase change.
- Recovery, Recrystallization, grain growth, softening.

4. DIFFUSION ANNEALING

- Alternatively called homogenizing annealing.
- Used to remove non-uniformity as it leads to brittleness and loss in toughness.
- Heated to:
  → 1000°C to 1200°C
  → Held for 10-20 hrs.
  → Slow cooling.
- Development of coarse grain, therefore further treatment to refine grains needs to be carried.
- Scaling occurs, leading to loss of material.
- Mainly used for hypoeutectoid or eutectoid steel.

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5. Process Annealing

- Heated below A_1 hold for sufficient time, then cooled slowly
- Reduces hardness and increases ductility
- Not same as recrystallisation annealing.
- Used mainly to counter excessive hardness and brittleness so that further processing can be carried out.

NORMALISING

- Heating to 40-50°c above A_3, holding followed by air cooling
- Pearlitic microstructure obtained.
- Better homogenisation, leading to better dispersion of ferrite and cementite phase.
- Normalising leads to:
  - → fine grain compared to annealing
  - → Machinability improves.
  - → Better ductility and strength.
- Normalising is heat treatment process which is similar to full annealing the only diff. is of fast cooling rate as compared to full annealing.

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SPHEROIDIZING

- Spheroidization of cementite takes place.
- Globules of cementite in ferrite matrix.
- Methods of spheroidization:
  - → Heat just below A_1 and holding, followed by slow cooling
  - → Alternatively heating and cooling just above and below A_1.
  - → Degree of spheroidization depends on temperature and time.
  - → High carbon and high alloy steel are spheroidized to improve ~~machinat~~ machinability and ductility.
  - → Low car steel if spheroidized becomes very soft.
  - → Cold worked material spheroidized faster
  - → Driving force is reduction in surface area of interface.

HARDENING

- Heating to hardening temp, holding and then quenching.
- Formation of martensitic structure
- Hardening temp:

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→ for hypo : 30°C to 50°C above A_3
→ for hyper : 30°C to 50°C above A_1
Presence of cementite in hyper-eutectoid case improves the wear properties.
Low tempr produces fine martensite.

- Tempering required to improve ductility and reduce strain.
- Hardening with tempering results in:
  → Improved wear property.
  → Optimum strength and ductility

TEMPERING :

- Heating to tempr below LCT followed by air cooling / furnace cooling.
- Reduces hardness, strength and wear resistance.
- Improves ductility, toughness.
- Relieves internal strain.
- Tempering embrittlement takes place at around 350°C - 600°C.
- Changes takes place during tempering :-
  → Carbon rejected by BCT martensite
  → Spheroidisation

→ Formation of ferrite and carbide mixture.

AUSTEMPERING

It is a heat treatment that is applied to ferrous metals, most ~~probably~~ notably steel and ductile iron. In steel, it produces a bainite microstructure.

- Austenite is converted to bainite.

MARTEMPERING

- Austenite is converted to martensite.
- Advantages.
  → Low internal stress
  → Less distortion.
  → Improved mechanical property.

→ The difference b/we Austempering & Martempering is:-

- In Austempering we used to cut bainite start and bainite finish curve to obtain 100% bainitic structure.
- In martempering we avoid even

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the bainite start curve, hold it as long as possible in order to get homogenous temp^r throughout the body.

SUB ZERO TREATMENT

- Used to reduce retained austenite.
- Cooling to -30°C to -70°C
- Results in :-
  - → Increased hardness
  - → Increased wear resistance.
- Increase in internal stress, tempering required.
- In sub-zero treatment we go really low temp^r thereby max. amnt of martensite is obtained.

CASE HARDENING

- It is the process of hardening the surface of a metal, thus forming a thin layer of harder metal (called the 'case') at the surface.
- It is usually done after the part has been formed into its final shape.
- It can provide a part that will not fracture (because

Of the soft core that can absorb stresses without cracking) but also provides adequate wear resistance on the surface.

Case Hardening

- Carburizing
- Cyniding
- Carbonitriding
- Nitriding

1. CARBURIZING

- Carbon is added to the surface of low carbon steel
- Two methods carburizing steel.

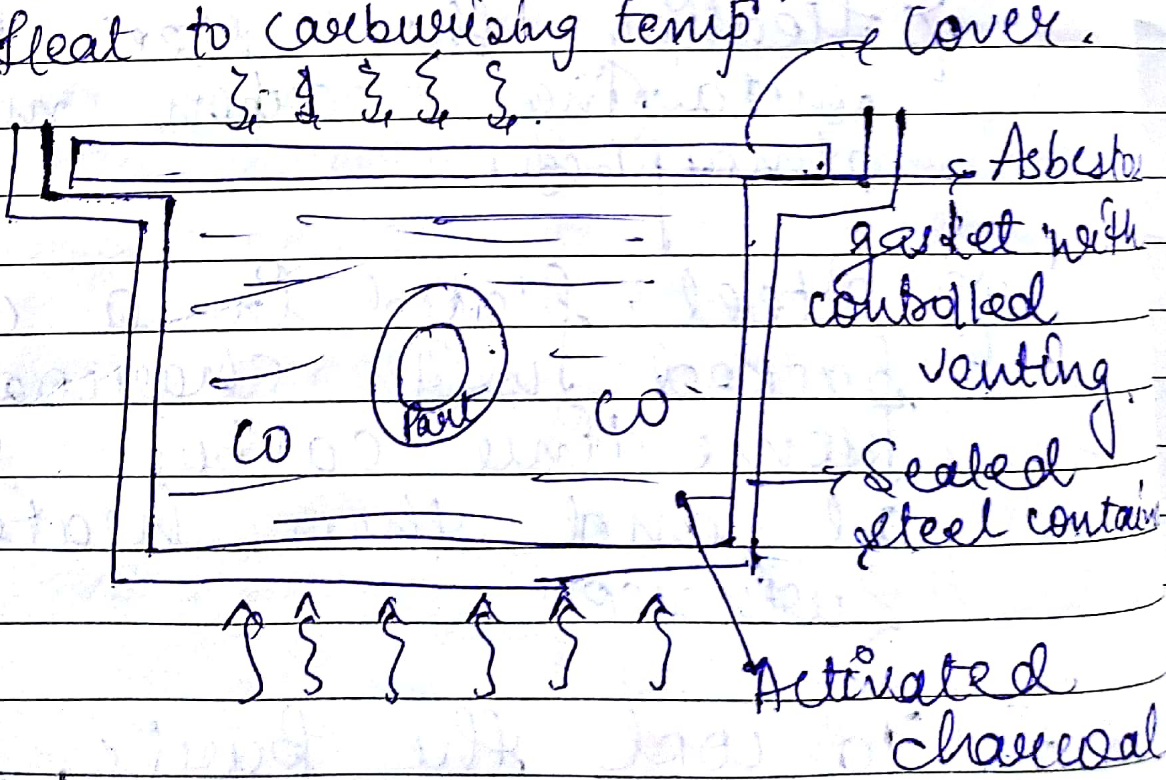
1. Heating the steel in a furnace containing carbon monoxide atmosphere.

2. Steel placed in a container packed with charcoal or some time carbon rich material and then heated in a furnace.

- To cool the parts, leave the container in the furnace to cool or remove it and let it air cool.

→ PACK CARBURIZING

- Part surrounded by charcoal treated with activating chemical then heated to austenite temp.
- Charcoal forms CO_2 gas which reacts with excess carbon in charcoal to form CO.
- CO reacts with low-carbon steel surface to form atomic carbon.
- The atomic carbon diffuses in the surface.
- Must then be quenched to get hardness.



→ LIQUID CARBURIZING

- It takes place in liq. medium
- The carburizing process is performed in baths of molten salts containing 75% sodium carbonate, 15% sodium chloride and 10% silicon carbide.
- Reac^n involved in this is:—

$$SiC + 2Na_2CO_3 \rightarrow \underbrace{Na_2SiO_3}_{\text{Slag}} + Na_2O + 2CO + C$$

→ GAS CARBURIZING

It is the process in which directly applied carbon monoxide gas reacts with the surface of a steel to give a much more direct and rapid absorption of carbon.

- This is achieved by holding the component in an atmosphere of a mixture of CO, CO_2, hydrogen and other gases.

2. NITRIDING

→ The diffusion of nitrogen in the surface layers of low carbon steels at elevated temp^r. The formation of nitrides in the surface layer creates increased mechanical properties.

- methods in that the individual parts have been heat-treated and tempered before nitriding.

- The parts are then heated in a furnace that has an ammonia gas atmosphere.

- No quenching is required so there is no worry about warping or other types of distortion.

- This process is used to case harden items, such as gears, cylinder sleeves, camshafts and other engine parts, that need to be wear resistant and operate in high-heat areas.

- more expensive than carburizing

3. CYANIDING.

- Fast and efficient
- Preheated steel is dipped into a heated cyanide bath and allowed to soak.
- upon removal, it is quenched and then rinsed to remove any residual cyanide.
- This process produces a thin, hard shell that is harder than the one produced by carburizing (completed in 20-30 min).
- Cyanide salts are deadly poison.

4. CARBONITRIDING.

- In this also same treatment as cyaniding, not by liquid salt baths but by gas atmospheres.
- In this, both carbon and nitrogen simultaneously saturate the surface of steel but the process is slower
- At low temp^r about 550°C

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this process is applied to HSS.
- This produces distortion free heat treatment.

SURFACE HARDENING

- In this the surface layers of a metal are hardened to a certain depth while the core is maintained relatively soft.
- In this heating and quenching of the metal is rapid and thus the core of the metal remains unaffected.
- Two methods of surface hardening
1. Induction hardening.
2. Flame hardening

1. INDUCTION HARDENING
- It is the process where steel is hardened by means of induction heating and subsequent quenching in ~~[illegible]~~ water.

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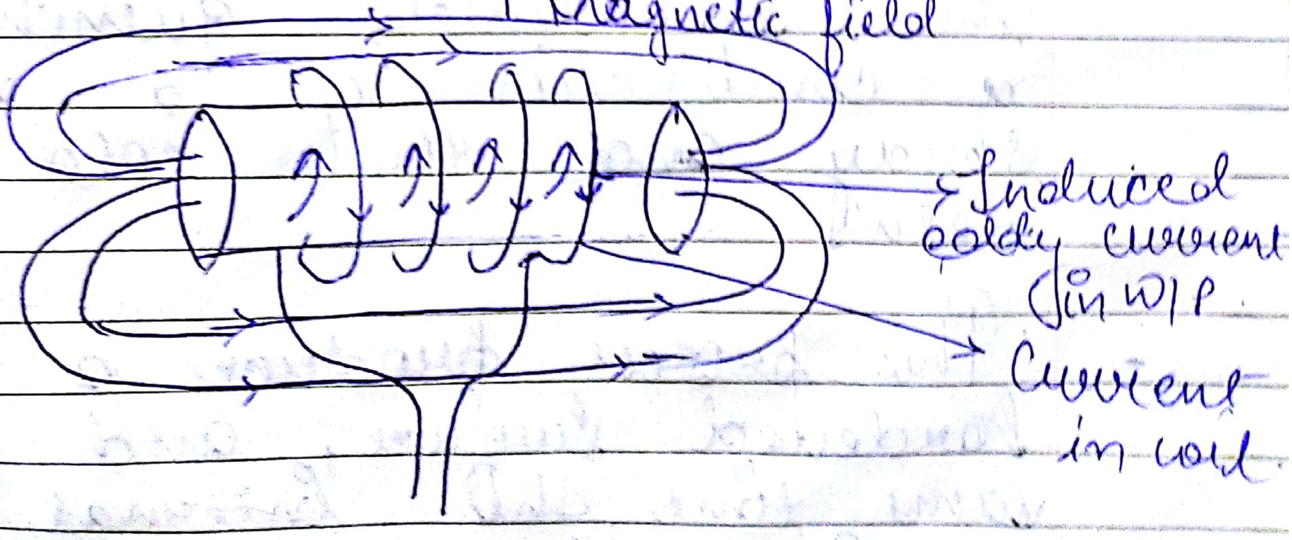
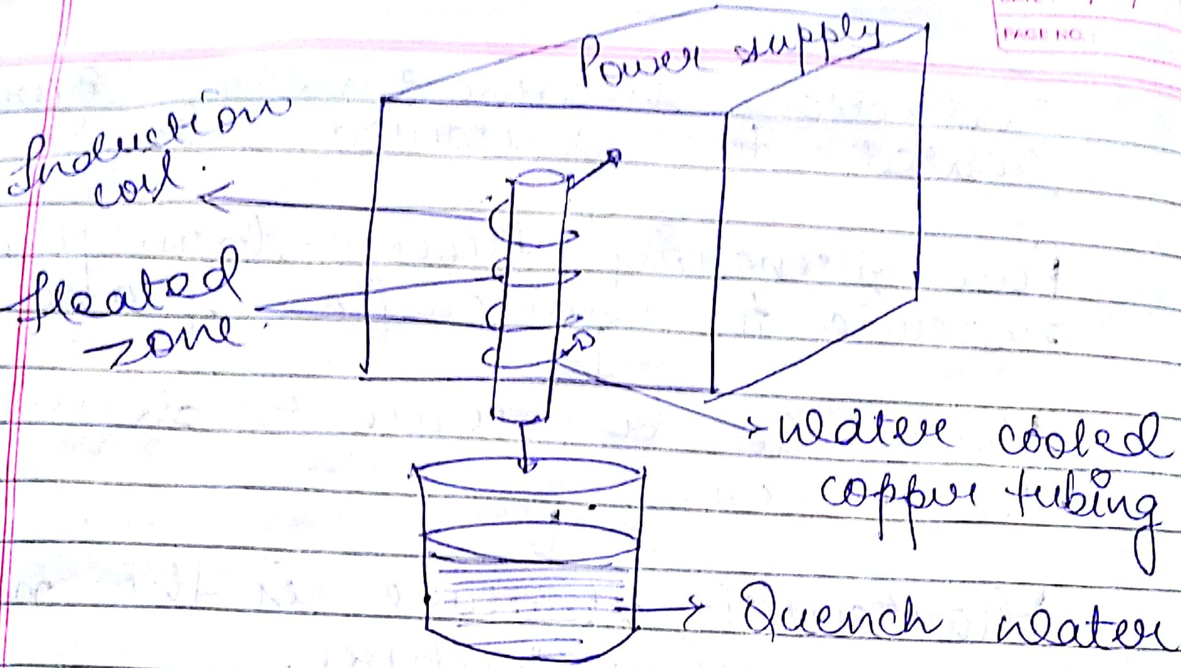
Induction heating : metal parts heated to austenite phase
↓
Fast quenching process transforms austenite to martensite phase
↓
Martensite ~~to~~ content determines the hardness.
↓
Martensitic structure is the most hardest microstructure.

Heating process → Joule heat by eddy current → Electromagnetic field
↓
High freq. AC power ← Induction coil.

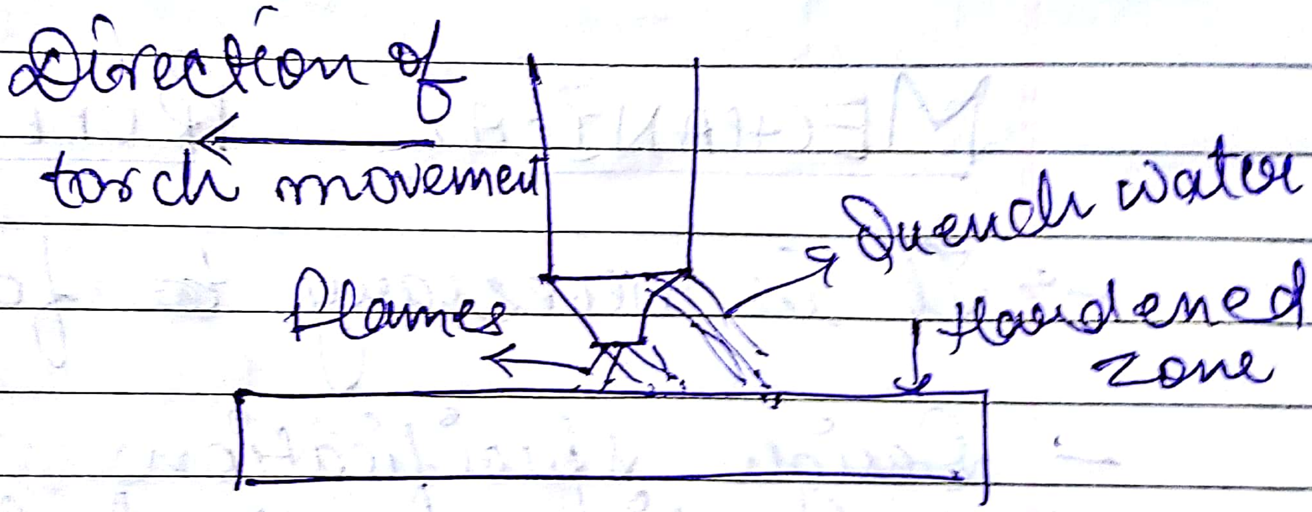




2). FLAME HARDENING

→ Harden the surface of metal parts. When you use an oxyacetylene flame, a thin layer at the surface of the part is rapidly heated to its critical temp^r and then immidiately quenched by a combination of a water spray and the cold base metal.

— This process produces a thin, hardened surface, and at the same time, the internal parts retain their original properties



Flame hardening process