HEAT TREATMENT

2.1 *<u>What is meant by heat treatment process? Give its purpose.</u>*

Heat treatment is the process of heating metal below its molten stage, and then cooling the metal in a controlled way to select desired mechanical properties.

PURPOSES (OR) OBJECTIVES OF HEAT TREATMENT:

- To harden and strengthen metals.
- To relieve internal stresses.
- To improve machinability.
- To improve ductility and toughness.
- To increase wear and corrosion resistance of metals.
- To improve electrical and magnetic properties.
- To refine grain size.

<u>(Mention the types of heat treatment processes.)</u>

2.2 TYPES OF HEAT TREATMENT PROCESSES

1. **Annealing processes.**
    - Full annealing
    - Stress – Relief annealing
    - Recrystallization annealing
    - Spheroidise annealing
2. **Normalizing**
3. **Hardening**
4. **Tempering**
5. **Austempering**
6. **Martempering**
7. **Case hardening**
    - Carburizing
    - Nitriding
    - Cyaniding
    - Carbon nitriding
    - Flame hardening
    - Induction hardening

<u>(Explain the various types of annealing?)</u>

1. **ANNEALING**

   It involves heating to a predetermined temperature, holding at that temperature and then cooling at a very slow rate.

Annealing is classified as,

a. Full annealing
b. Stress relief annealing
c. Recrystallization annealing
d. Spheroidising annealing

a. Full annealing

- Full annealing consists of heating steel to above the upper critical temperature, and slow cooling, usually in the furnace.
- This method is suitable for high carbon steels.
- This consists of holding the steel at a selected temperature above the upper critical temperature for sufficient time to allow transformation to pearlite before cooling the steel.
- It requires long time and therefore an expensive method.

Purpose

- refines grains, removes strains
- Improves machinability, formability, electrical and magnetic properties.

b. Stress relief annealing

- an after-treatment procedure to reduce inner stress within the castings through annealing and slow cooling-down, thereby reducing the risk of dimensional changes during manufacturing or final use of the component.
- It relieves stresses produced by casting, quenching, machining, cold working, welding etc.
- It applies equally well to ferrous and non – ferrous metals.

c. Recrystallization Annealing:

- It is carried out by heating the steel to a temperature below the critical temperature (600 – 700^{o}C) and slow cooling.
- The recrystallization annealing temperature is not fixed.
- This treatment is used in sheet and wire industries.
- It is used to reduce the distortions of the crystal lattice produced by cold working.

d. Spheroidising Annealing:

- Heating the steel to a temperature above the critical point and holding at that temperature followed by slow cooling (25 to 30^{o}C per hour) to 600^{o}C within the furnace.

Purpose

- improves machinability of high carbon steels.
- Prevents cracking of steel during cold forming operations.
- Better strength and ductility can be obtained.

2. Normalizing

Steel is heated to about 40 – 50^{o}C above the upper critical temperature held at that temperature for a sufficient period of time and then cooled in still air to room temperature.

Purpose of normalizing

- to refine the grain structure
- obtain a homogenous structure
- decrease - residual stress
- improves-machinability.

<u>(What is quenching?)</u>

3. Hardening or (Quenching)

- Hardening treatment consists of heating the steel to hardening temperature, holding at that temperature for a particular time followed by rapid cooling in water, oil or brine solution.

- Hypo eutectoid steels are heated to about 30- 50oc above the upper critical temperature.
- Hyper eutectoid steels are heated to about 30-50oc above the lower critical temperature.

Purpose of hardening

- Tensile strength and yield strength are improved.
- The wear resistance and cutting ability of steel are increased.

(What is tempering? Explain the types of tempering.)

4. Tempering

- It is a heat treatment followed after hardening and involves heating the hardened steel to some temperature below the lower critical temperature soaking at this temperature for sufficient time followed by slow cooling in air.

Purpose of tempering

- To relieve the residual stresses and improve ductility and toughness of the hardened steel.

Types of tempering based on heating temperature

a. Low temperature tempering (1-2 Hours at a Temperature up to 250°C)

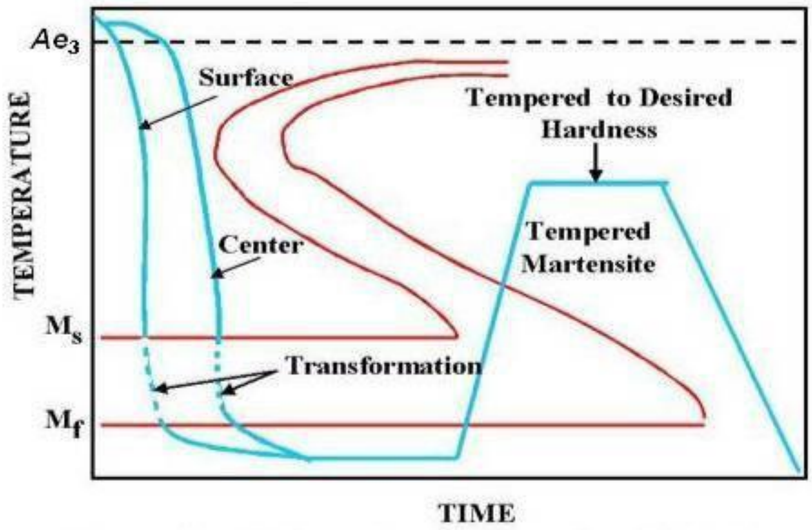
- This treatment is given normally to tools of plain carbon and low alloy steels, to develop high cutting-ability, wear and abrasion resistance with some toughness.
- Reduces the brittleness of steel and increases the toughness.

b. Medium temperature tempering:**(350 C to 500°C)**

- Increase of ductility and toughness.
- Decrease in hardness and strength.

c. High temperature tempering(500-650°C)

- This treated steel has better tensile yield and impact strength and is free from internal stresses.
- This structure is very soft and tough.

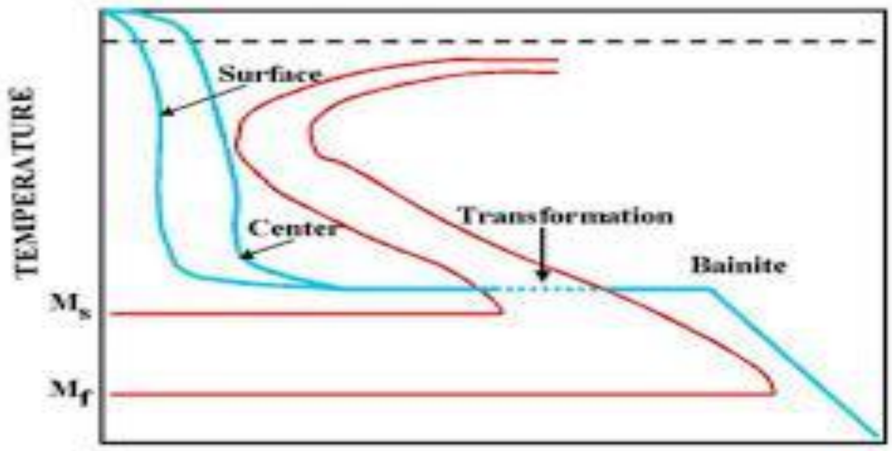


(Explain aus tempering.)

5. Aus tempering

- heat treatment process used to obtain a bainite structure.
- Heating the steel to proper austenitising temperature (725- 1370 ºC). Quenching in a salt bath having temperature from 250oc to 300oc.

- Held at this temperature for a long time as is needed for the transformation of austenite.
- Since the quenching bath temperature is higher than the Ms temperature, the austenite is transformed in to bainite.



Purpose of austempering

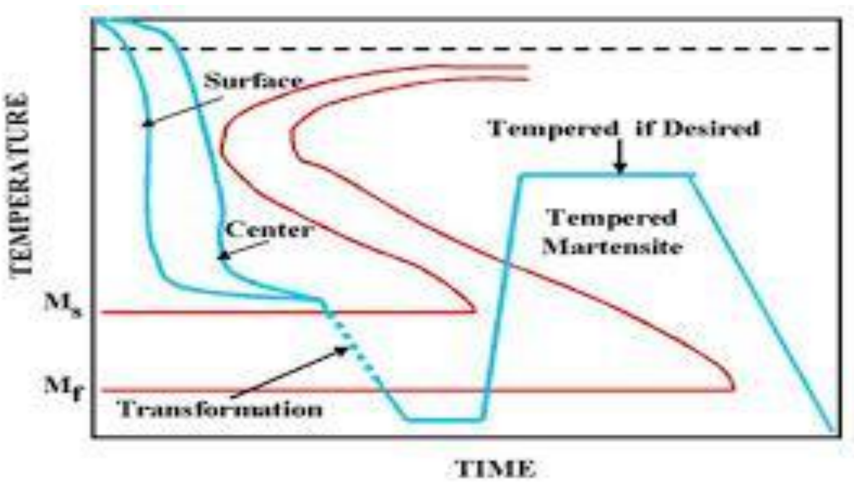
- has high hardness and ductility.
- Residual stress - reduced.
- less of hardening, cracks and wastage.
- Very thick sections cannot be heat treated.
- Long time is needed for the isothermal transformation of austenite to bainite.

(Explain martempering.)

6. Martempering

- Steel is heated to above the critical range to completely become Austenite. Temperature at 180 – 250oc maintained above Ms. Quenching in a liquid medium. Cooling in air to room temperature.
- Steel has less tendency to crack, distort and develop residual stresses during heat treatment.

- Large sections cannot be treated by martempering because the time required to obtain uniform temperature is too long.
- more suitable for high carbon steels and alloy steels.



(Explain the various methods of surface hardening or case hardening)

7. Case Hardening: (Surface Hardening)

- Hardening by diffusion of elements like carbon, Nitrogen in to the surface of a non-hardenable steel.
- These elements alter the composition of the surface by forming compounds (carbides, Nitrides) which are inherently hard.
- This produces a potentially hard surface skin.

The various processes are:

a) Carburizing
b) Nitriding
c) Carbon nitriding
d) Cyaniding

(Explain the process of carburizing with its types.)

a) Carburizing

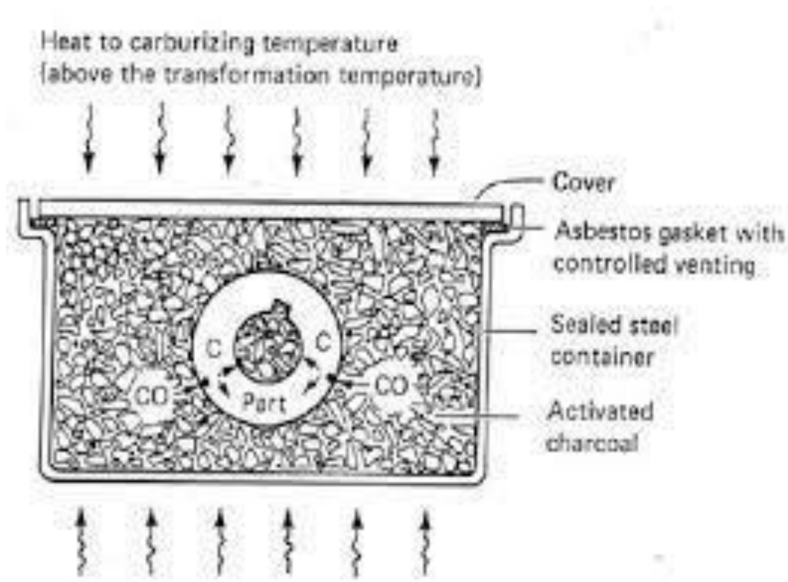
It is a method of diffusing carbon into the surface layer of low carbon steels in order to produce a hard surface. The depth of surface is 0.5 to 2mm. Temperature ranges from 900- 930^{o}C.

Methods of carburizing

i). Pack carburizing (Solid)
ii). Liquid carburizing
iii). Gas carburizing

i). Pack carburizing

- Pack carburizing is otherwise known as solid carburizing. The machined components of low carbon steel which are to be heat treated are packed with 70% charcoal and 30% barium carbonate.
- The components are packed in a steel box. The boxes are then place in a furnace and heated to a temperature of 900- 950oc for 6 to 8 hours.
- After heating, the box is cooled to the room temperature along with the components.



The following reactions takes place in this process.

$BaCO_3 \rightarrow BaO + CO_2$ (Formation of carbon dioxide)

$CO_2 + C \rightarrow 2CO$ (Dissociation of CO2)

$2CO + 3Fe \rightarrow Fe_3C + CO_2$ (Enrichment of steel)

Advantages

- This method is more efficient.
- It is the cheapest method.
- It is suitable for large parts.

Disadvantages

- It is not suitable for thin cases.
- It does not provide close control on tolerances.
- More time is required.

ii). Liquid carburizing

- It is carried out in molten baths, containing 20 to 50% sodium cyanide, 40% sodium carbonate and varying amounts of sodium or barium chloride.
- The mixture is melted and the bath temperature is maintained between 815oc and 900oc. The components are in molten bath for a period of 5 minutes to 1 hour.

The following reactions are,

$BaCl_2 + 2NaCN \rightarrow Ba(CN)_2 + 2NaCl$

$Ba(CN)_2 + Fe \rightarrow FeC + Ba(CN)_2$

Advantages:

- Uniform heat transfer.
- Less time is required.
- Rapid rate of penetration.
- Uniform case depth and carbon content.
- Low distortion.

Disadvantages:

- Cyanide salts are highly poisonous.
- Parts should be thoroughly washed after treatment to prevent rusting.

iii) Gas carburizing:

- The components are heated to a temperature of about 900oc for 3-4 hours and steel is heated in contact with hydro carbons like methane, ethane with carrier gases like N_2, H_2 and CO.

The following reactions takes place

$$3Fe + CO + H_2 \rightarrow Fe_3C + H_2O$$
$$3Fe + 2CO \rightarrow Fe_3C + CO_2$$

Advantages:

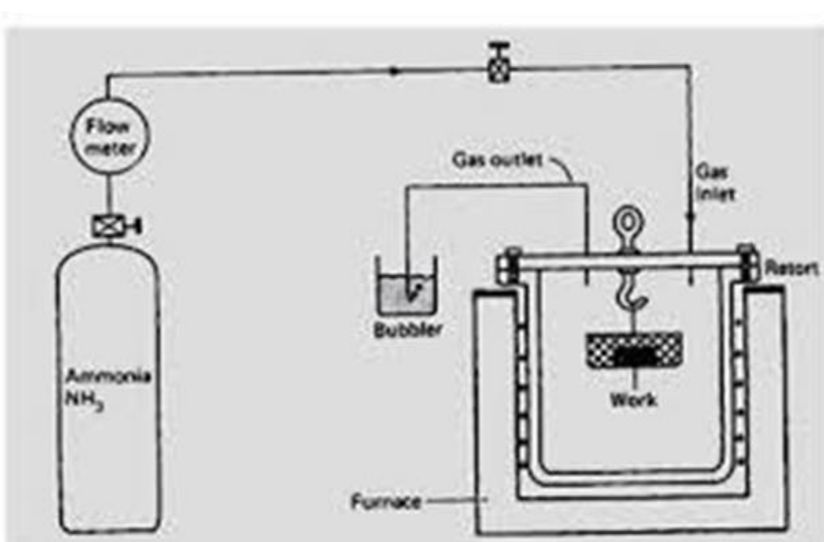
- It is suitable for mass production.
- Less time is required for the operation.
- Close control on tolerance can be obtained.

Disadvantage:

- Highly skilled labours are required.
- Labour cost is also less.

b. Nitriding

- It is process of coating steel surface with nitrogen. Ammonia gas (NH_3) is coated on the surface of steel at temperature ranging from 480°c to 650°C.
- The components are placed in furnace which is then filled with ammonia solution. Then the temperature is raised from 480° to 650°C and from 0.2 to 0.4 mm deep.
- Nitriding is usually applied to medium carbon steels and alloy steels containing A1, Cr, Mo.



Advantages :

- ✓ High surface hardness.
- ✓ Increases the wear resistance of steel.
- ✓ Corrosion resistant.
- ✓ Good Fatigue resistance.
- ✓ No machining is required.
- ✓ No quenching is obtained.
- ✓ Hardening defects are avoided.

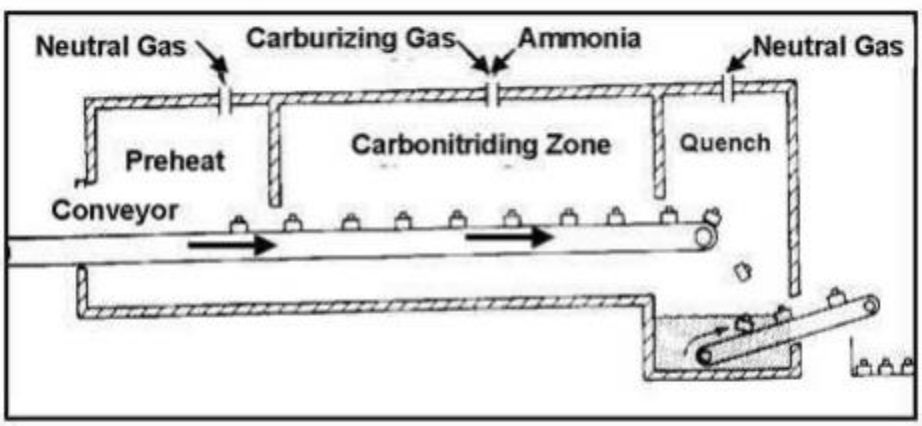
Disadvantages:

- ✓ It requires more time.
- ✓ Cost of ammonia is high.
- ✓ Long cycle time.
- ✓ Technical control is required.
- ✓ It is hard and brittle.

c. Carbon Nitriding:

Carbon nitriding is **a heat treatment process by which carbon and nitrogen (via ammonia gas) permeate the surface layer of steel components**.

- ➢ The gas mixture consists of a carburising gas which is a mixture of methane (5%) ammonia (15%) and remaining neutral gas.
- ➢ The hardness obtained in steel is RCE65. The case depth obtained in nearly 0.5mm.



Advantages:

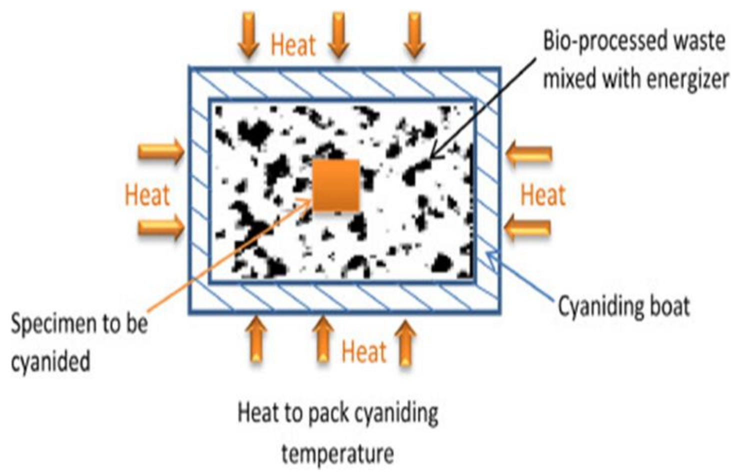
- ➢ Low heat treating temperatures are required.
- ➢ Less quench is needed.
- ➢ Reduced the distortion.
- ➢ Better wear resistance and surface harden ability.
- ➢ The process involves temperatures of around 850°C followed by quenching in oil or gas solutions.

Applications:

- It is used bolts, nuts, gears etc.

d. Cyaniding:

- It is process in which both carbon and nitrogen are coated to the surface layer of steel. Its depth ranges from 0.1 to 0.2 mm.
- The components are immersed in a liquid bath of 30% NaCN, 40% Na_2CO_3 and 30% NaCl at 800°C to 850°C.
- Then a measured amount of air is passed through the molten bath.
- The mixture is then held at this temperature for a period of 30 minutes to 3 hours.
- Then the cyanide compounds decompose and easily release the carbon and nitrogen atoms.



The reaction taking place is,

$$2NaCN + CO_2 \rightarrow Na_2CO_3 + CO + 2N$$

$$3Fe + 2CO \rightarrow Fe_3C + CO_2$$

$$Fe + N \rightarrow FeN$$

Advantages:

- This process increases the surface hardness.
- This also increases wear resistance and fatigue limit.

Applications:

- It is suitable for small parts such as gears, pistons, pins small shafts etc.

2.3 SELECTIVE HARDENING

Hardening by phase transformation through rapid heating and cooling of the surface of a hardenable steel is called selective hardening. This method do not alter the composition of the steel.

The Processes are:

1. **Flame hardening**
2. **Induction hardening**
3. **Vacuum hardening**
4. **Plasma hardening**

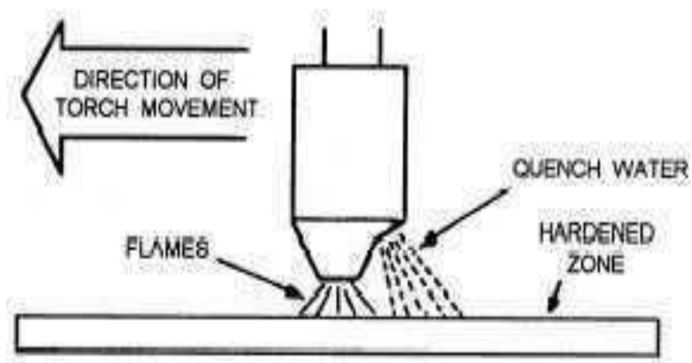
(Explain flame hardening and induction hardening.)

1. **FLAME HARDENING**

   Flame hardening is the process of selective hardening with a combustible gas flame as the source of heat for austenitising.

   Principle of flame hardening:

   - The surface to be hardened is heated to a temperature above its upper critical temperature, by means of a travelling oxy-acetylene torch.
   - Then it is immediately quenched by a jet of water issuing from a supply built into the torch-assembly.
   - Thus the surface hardening results when the austenitized surface is quenched by the water spray that follows the flame.



Suitability:

- The flame hardening technique is suitable for the **plain carbon steels with carbon contents ranging from 0.40% to 0.95% and low alloy steels.**

Advantages:

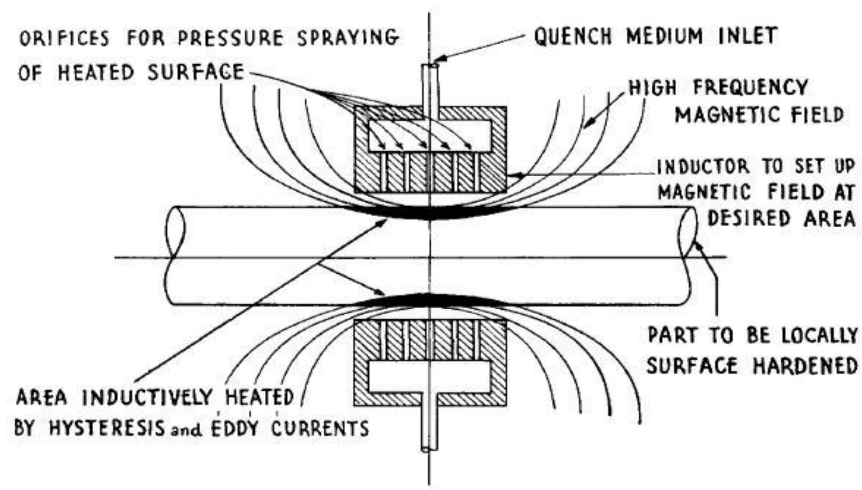
1. The process is more efficient and very economical for larger works.
2. As heating rate is high the surface of work remains clean.

Disadvantages:

1. very thin sections may get distorted excessively.
2. overheating may cause cracks.

2. INDUCTION HARDENING

- The heating in this process is done within a thin layer of metal surface by high frequency induced currents.
- A high frequency current is passed through the primary coil. This generates alternate magnetic field. This magnetic field induces eddy currents of the same frequency in the surface layer which heat the surface of the components.
- Within a short period of 2 to 5 minutes the temperature of surface layer comes to above the upper critical temperature of the steel.
- The component is quenched by water spray usually without removing the inductor coil. Due to fast heating and no holding time, Austenite is transformed in to fine grained Martensite.
- Induction hardening is commonly followed by low temperature tempering at 160 to 200 ^{o}C.
- Steels with carbon between **0.4 to 0.5%** are hardened by this method.



Advantages:

- Fast heating.
- No holding time.
- Increase the production rates.
- Low alloy steels are also surface hardened.
- Easy control the depth of hardening.

Disadvantages:

- High equipment cost.
- Irregular shapes cannot be used.
- High Maintenance cost.

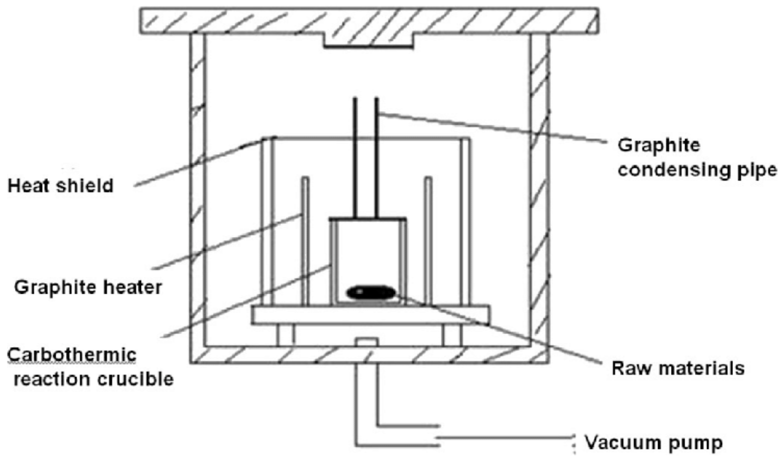
Applications:

- Cylinder liners, machine tool ways, pump shafts.

(Explain vacuum hardening and plasma hardening.)

3. VACUUM HARDENING

- Vacuum hardening is one of the methods to protect heated steel and metal parts from the negative influence of an air.
- A vacuum furnace is normally an electrically heated furnace in which vacuum is maintained during the process.
- Vacuum hardening is the hardening of components under a controlled partial pressure, during which temperatures of up to 1,300°C can be reached.
- Aims to create bright metallic work piece surfaces which render further mechanical processing unnecessary.



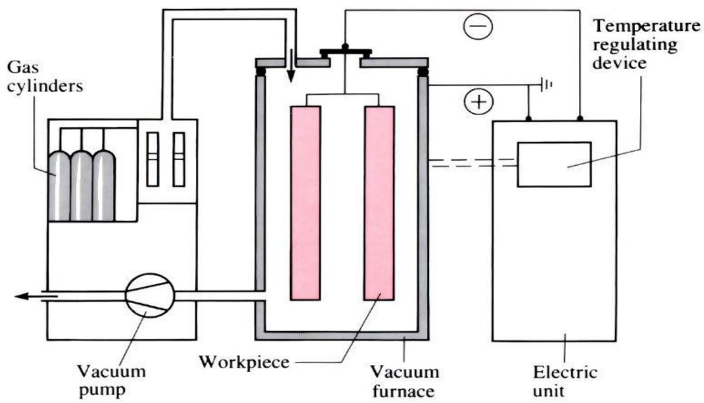
Advantages

- It comes out harder and resists corrosion better.
- It also has more tensile strength, shear strength, ductility, and elasticity.

4. PLASMA HARDENING

- Plasma technology is primarily for stainless steel and other low alloy steels which are not suitable for a "standard" heat treatment process.
- The process uses a Plasma discharge of Hydrogen and Nitrogen gases both to heat the steel surfaces and to supply nitrogen ions for nitriding.
- **PLASMA CARBURIZING PROCESS**, also called **ion carburizing**, making use of a high-voltage electrical field applied between the load and the furnace wall, producing activated and ionized gas species responsible for the carbon transfer to the work pieces.
- Plasma Nitriding is a surface hardening process, in which nitrogen is diffused in to the components surface.
- Plasma nitriding produces high surface hardness, good wear resistance, increased fatigue strength and toughness.

Gas plasmas are ionized gases formed by liberating electrons from gas molecules and atoms using external energy sources such as lasers or high electrical voltages.



(Define hardenability. Explain the method of determining hardenability.)

2.4 HARDENABILITY

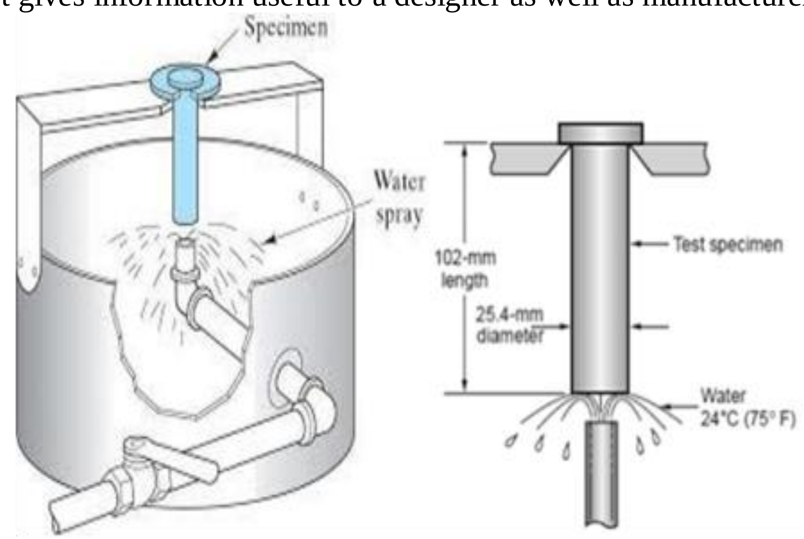
The hardenability of a metal alloy is the depth to which a material is hardened after putting it through a heat treatment process.

Factors affecting hardenability:

- The composition of the steel
- The austenitic grain size.
- The structure of the steel before quenching.
- The quenching medium and the method of quenching.

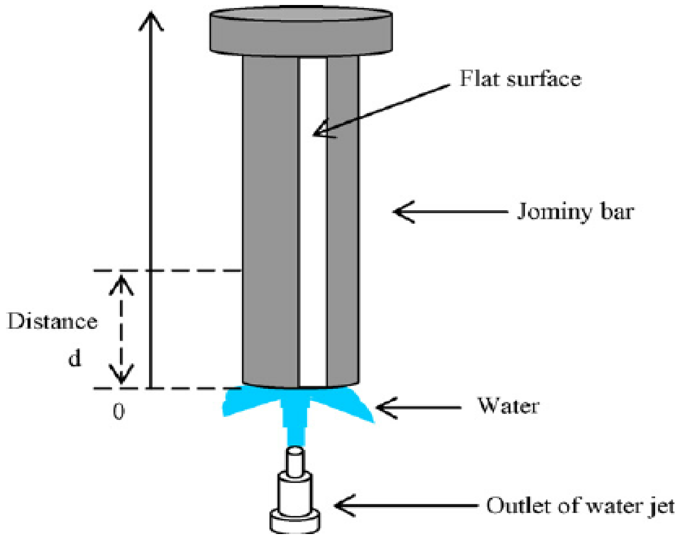
Determining hardenability (Jominy End Quench test):

1. **Importance of Jominy End Quench test**
    - o It is relatively easy to perform.
    - o It is excellent reproducibility.
    - o It gives information useful to a designer as well as manufacturer.

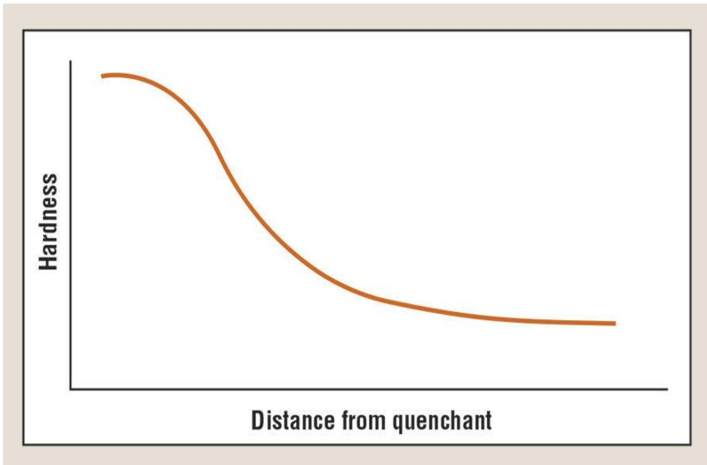


2. **Process:**

- Specimen of cylindrical shape of diameter 25.4mm (1inch) length of approximately 102mm.(4 inch) is heated in a furnace.
- austenizing temperature (725°C -1330°C) is maintained for a prescribed time.
- It is removed from furnace and placed in a fixture (stand like)
- Lower end of specimen is quenched in a jet of water from nozzle.
- cooling rate is high at thequenched end and reduces along the length of the specimen.
- Hardness drops off rapidly a short distance from the quenched end.



- A flat 0.4mm deep flat surface is cut along the length of the bar.
- **Rockwell C hardness measurements** are taken at **1.5 mm intervals from quenched end** and hardness readings are taken.
  - Hardenability curves are plotted.



3. **Inference**
   - ➢ Quenched end – maximum hardness – 100% martensite is the product at quenched end.
   - ➢ Cooling rate decreases – hardness also decreases.

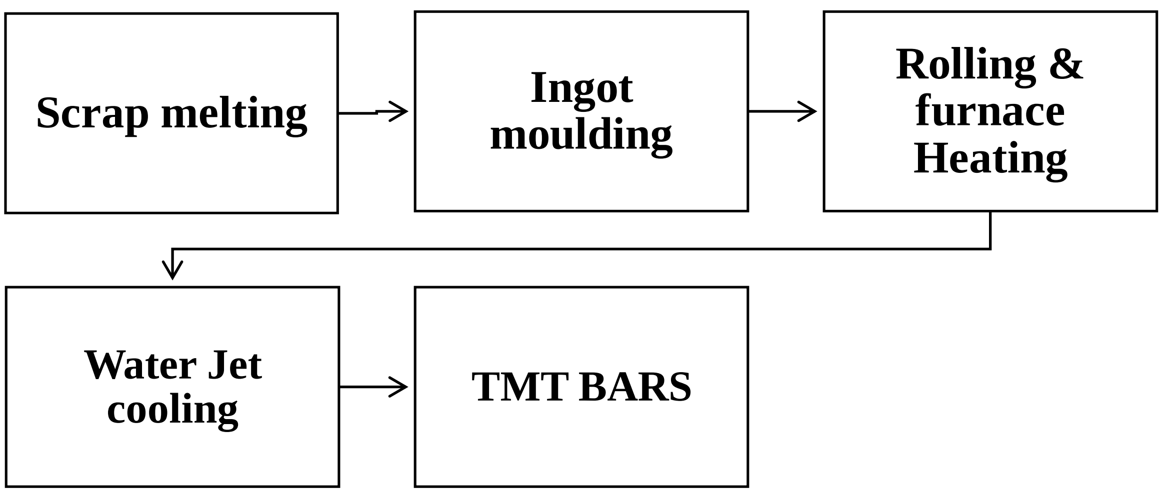
2.5 THERMO-MECHANICAL TREATMENTS(TMT)

- ➢ Thermo-mechanical treatment is the simultaneous heating and cooling of steel to develop better properties in steel by refining its micro structure.
- ➢ This heating technology is referred as hot rolling in this process vast quantities of steel can be handled.
- ➢ Temperature in rolling mill is between 1200 – 1300°C.

Purpose of thermo-mechanical treatment

- ➢ Steel gains high strength &ductility.
- ➢ Steel turns into ferrite pearlite structure which means that the outer core becomes strong and inside remain soft.

Steps involved in manufacturing TMT bars



Few important facts on Thermo mechanical Treatment

- Austenite is formed that is far superior to ordinary steels and hardening takes place during the controlled cooling process.
- Carbon ratio in TMT Bars is as low as 0.5% therefore the tensile strength is high and less brittle.
- Tempering is done at 100°C that increases the strength and ductility.
- During thermo- mechanical treatment superior ductility enhances in TMT bars therefore, the austenite causes the balance between Strength and Flexibility.
- The brittle strength increases in TMT Bar relatively. That is why it becomes usable for any type of construction purposes.
- The Martensite structure consists of consistent RIBS that give superior bonding quality of steel bars in RCC.

Advantages of TMT bars:

- TMT Bars comes with better strength & superior Elongation than any other type of steel bars.
- It saves up to 17% of steel.
- The cost of TMT Bars is lower than other types of steel bar.
- Better Ductility & Bendability favours it to use for any type of construction structure and saves time as well.
- TMT Bars are Resistant to Fire and Corrosion that is why worldwide the demand of TMT Steel Bars are higher.
- The fatigue strength in TMT Bar is high, so, during the construction it can bend as per the requirement.

(What are Iso-Thermal Transformation Diagram (TTT) diagrams? Explain the construction of TTT diagram.)

2.6 ISO – THERMAL TRANSFORMATION DIAGRAM

What is isothermal phase transformation?

- A phase transformation occurs at a constant temperature (isothermal); this is known as isothermal phase transformation.

Iso-Thermal Transformation Diagram

- generated from **percentage transformation Vs time measurements at fixed temperature.**
- useful for **understanding the transformations of an alloy steel at elevated temperatures.**
- Isothermal transformation diagram is otherwise known as S-curve, Bain's curve or T.T.T. (Time – Temperature- Transformation) diagram.

Steps to construct isothermal transformation diagram

Step 1:

- Obtain a large number of relatively small specimens of same material.

Step 2:

- Austenize the samples in a furnace at a temperature above the eutectoid temperature.

Step 3:

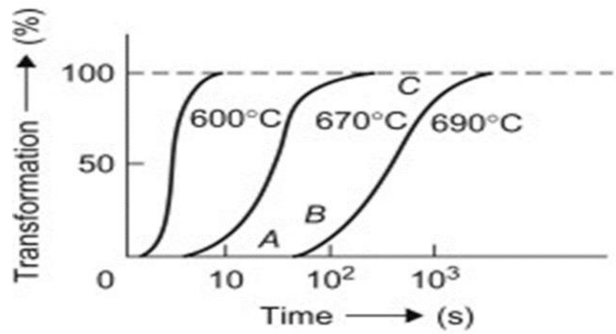
- Then quench the samples in a liquid salt bath at the desired temperature below the eutectoid temperature.

Step 4:

- At various time intervals, remove the samples from the salt bath one by one at a time and quench into water at room temperature.

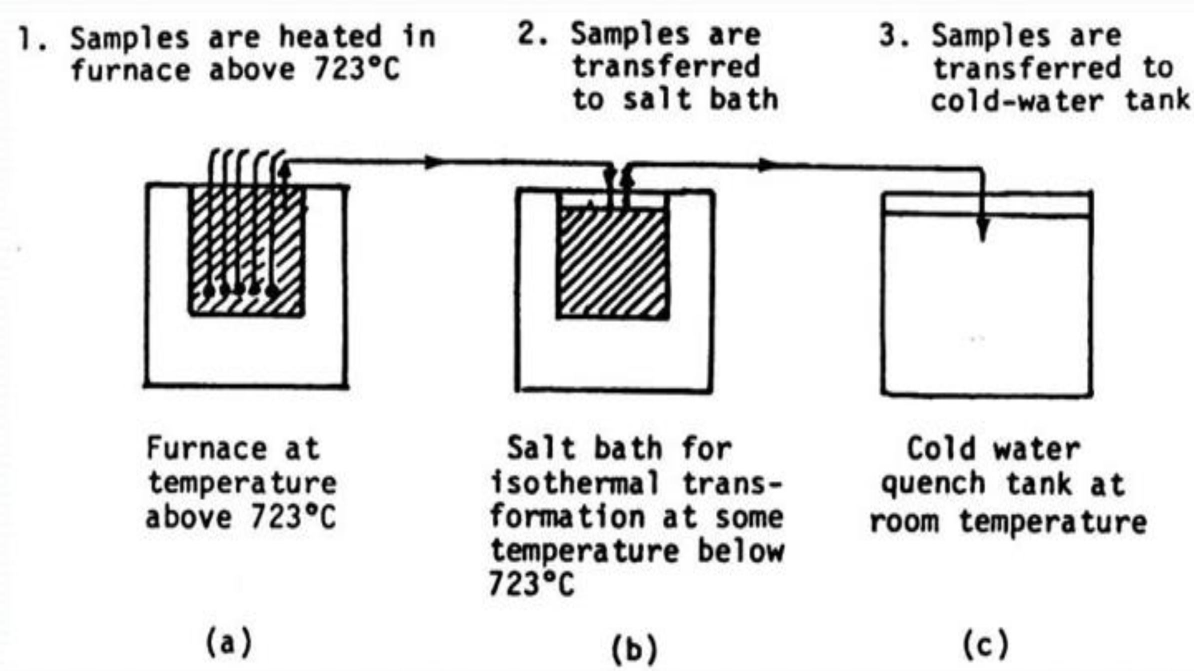
Step 5:

- Now, examine the microstructure after each transformation time at room temperature. The result obtained is the **reaction curve**.

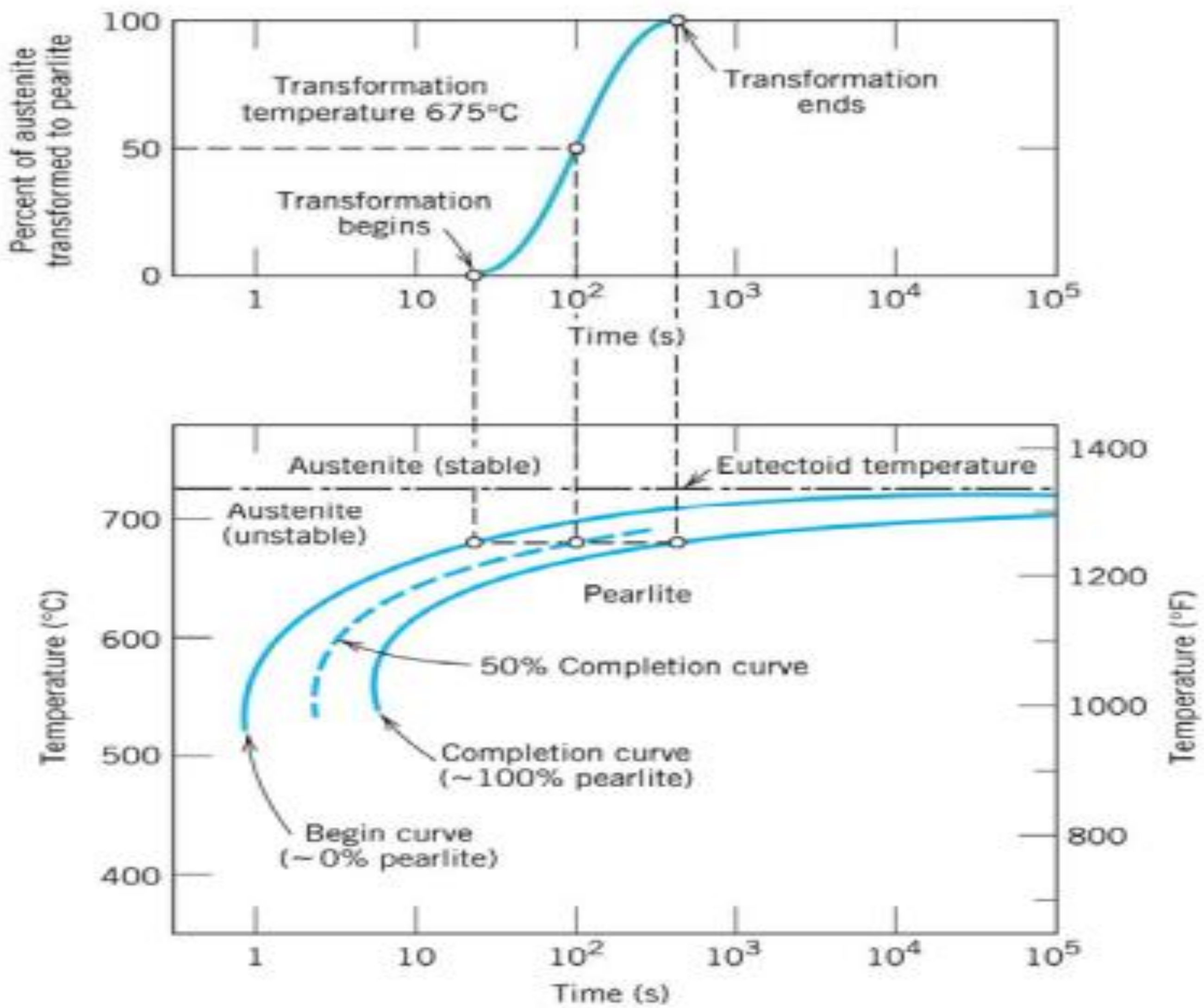


Step 6:

- Now, repeat the procedure at progressively low temperatures.
- The data obtained from a series of isothermal reaction curves over a whole range of austenite instability for a given composition of steel is the TTT diagram for steel.



Experimental arrangement for determining the microscopic changes that occur during the isothermal transformation of austenite in an eutectoid plain-carbon steel



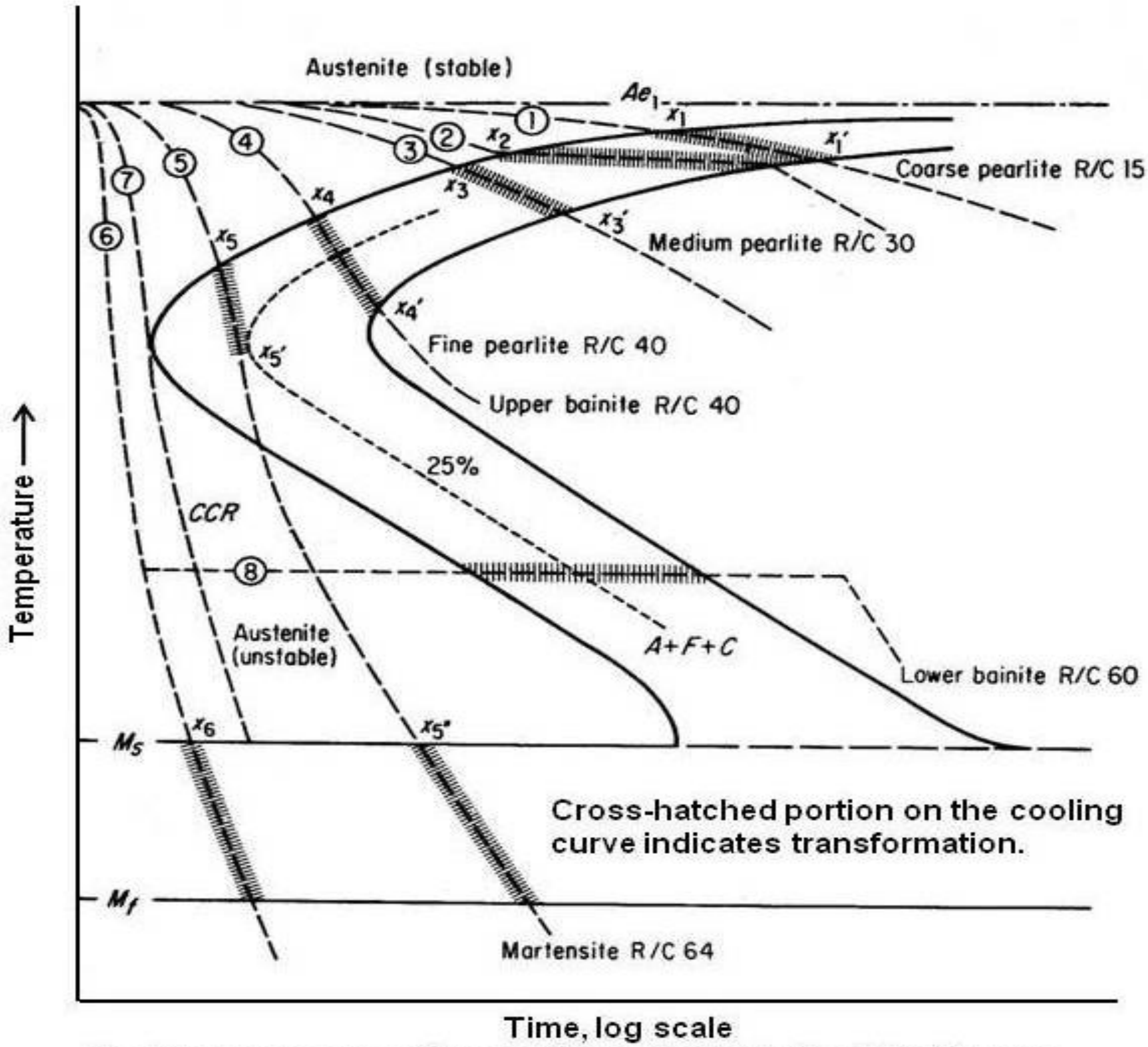
<u>(Explain the superimposition of cooling curves on TTT diagrams.)</u>

2.7 Cooling Curves superimposed on Isothermal Transformation Diagram

A cooling curve is determined experimentally by placing a thermocouple at a definite location in a steel sample and then measuring the variation of temperature with time.

1. Cooling Curve 1:

Cooling curve 1 shows a very slow cooling rate and this corresponds to conventional annealing. The transformation will start at point $\mathbf{x_1}$. The transformation product at that temperature coarse pearlite. The transformation will continue till point $\mathbf{x_1'}$.



Cooling curves superimposed on a hypothetical I-T diagram

2. **Cooling Curve 2:**

   Cooling curve 2 illustrates isothermal annealing.The process is carried out by cooling the material above A1 line and holding at that temperature to produce complete transformation. The transformation product is medium pearlite. This heat treatment produces more uniform structure and hardness.

3. **Cooling Curve 3:**

   This curve has a faster cooling rate than annealing. It may be considered as typical normalizing. Transformation starts at $\mathbf{x_3}$ and ends at $\mathbf{x_3'}$. The product formed is fine pearlite.

4. **Cooling Curve 4:**

   Cooling curve 4, typical of a slow oil quench, and the microstructure will be a mixture of medium and fine pearlite.

5. **Cooling Curve 5:**

   Cooling curve 5, typical of an intermediate cooling rate, and austenite will start to transform to fine pearlite from**x_5**. As **Ms** line is crossed the remaining austenite will transform into martensite. The final microstructure at room temperature will consist of 75 percent martensite and 25 percent fine nodular pearlite.

6. **Cooling Curve 6:**

   Cooling curve 6, typical of a drastic quench, is rapid enough to avoid transformation in the nose region. It remains austenitic until the M_s line is reached at x_6. Transformation to martensite will take place between M_s and M_f lines. The final microstructure will be entirely martensite of high hardness.

7. **Cooling Curve 7:**

   This curve is tangent to the nose region and corresponds to critical cooling rate(CCR). Any cooling rate slower than the CCR will produce softer transformation product like pearlite. Any

   cooling rate faster than the CCR will produce harder transformation product like marttesite. Steels can be classified based on their CCR's.

8. **Cooling Curve 8:**

   It is possible to form 100% pearlite or martensite by slow cooling but it is impossible to form 100% bainite. This cooling curve obtains a bainite structure by cooling rapidly to avoid transformation at the nose region and then holding in the temperature range of 300-350°C at which bainite is formed until transformation is complete.

<u>(What is critical cooling rate? Give its importance.)</u>

2.8 CCR (CRITICAL COOLING RATE):

The slowest rate of cooling of austenite that will result in 100% martensite transformation is known as the critical cooling rate.

Importance:

- most important in hardening.
- To obtain 100% martensite structure on hardening the cooling must be much higher than the critical cooling rate.

Factors affecting CCR:

1. Chemical composition of steel.
2. Hardening temperature
3. purity of steel

<u>(Explain about CCT diagrams.)</u>

2.9 Continuous Cooling Transformation Diagram (CCT diagram)

- A continuous cooling transformation (CCT) phase diagram is often used when heat treating steel. These diagrams are used to represent which types of phase changes will occur in a material as it is cooled at different rates.
- CCT diagrams depict transformation, temperature and time relationship during continuous cooling.

- Specimen are cooled from austenitic range at a constant cooling rate and pearlitic start and finish are points are determined. Experiments with different cooling rates yield the locus of the two points and hence CCT diagrams are constructed.

Difference between TTT and CCT

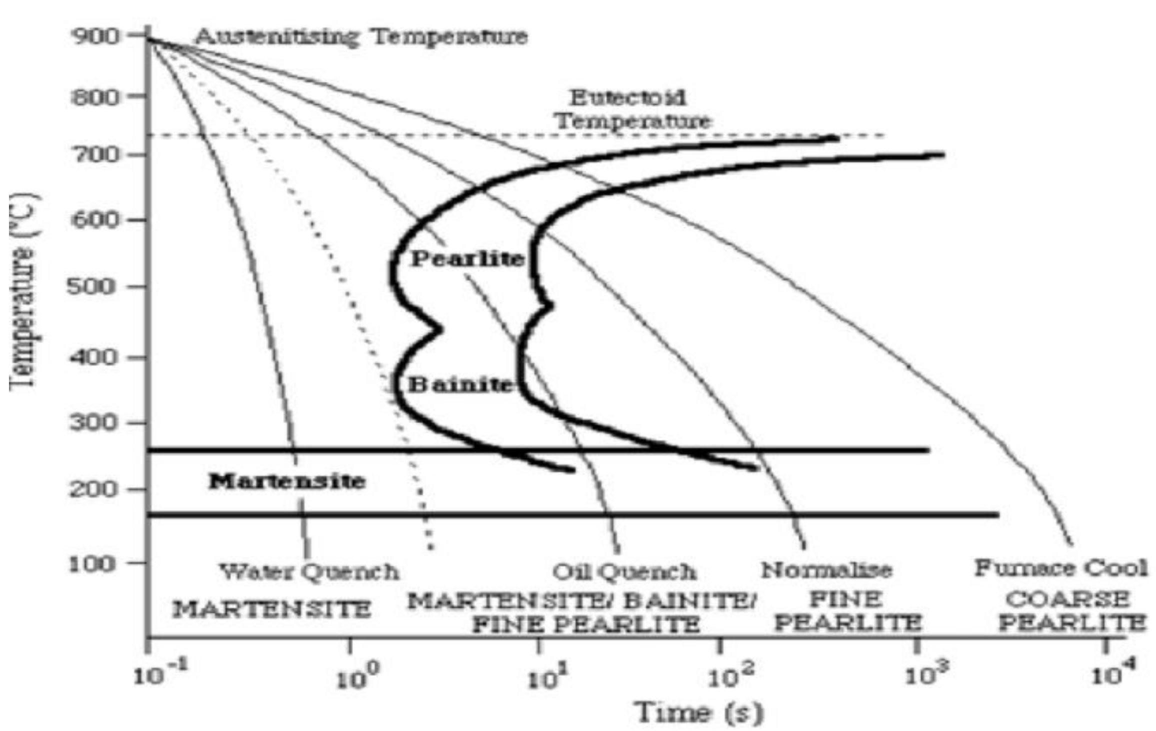
- TTT diagrams examine the progress of transformation as a function of time, at a fixed temperature.
- CCT diagrams examine the progress of transformation as a function of changing temperature.

Types of CCT diagrams

There are two types of CCT diagrams

1. Plot of transformation start, specific fraction of transformation and transformation finish temperature against transformation time on each cooling curve.
2. Plot of transformation start, specific fraction of transformation and transformation finish temperature against cooling rate.

CCT diagram for a eutectoid steel is given below,



Factors affecting CCT Diagram

1. **Grain Size**
2. **Carbon content**
3. **Alloying Elements**

1. **Grain Size**
   - Fine grain steels tend to promote formation of ferrite and pearlite from austenite.
   - Hence decrease in grain size shifts the TTT diagram towards left.
   - Therefore, CCR increases with decrease in grain size.

2. **Effect of carbon content**
   - An increase in carbon content shifts the CCT and TTT curves to the right. This corresponds to the increase in hardenability as it increases the ease of forming martensite.
   - An increase in carbon content decreases the MS, the martensite start temperature.

3. **Effect of Alloying Elements**
   - An increase in alloy content shifts the TTT and CCT to the right.
   - Alloying elements also modify the shape of TTT diagram and separate the ferrite + pearlite region from bainite region making the attainment of the bainitic structure more controllable.

2.10 Elementary Ideas on Sintering

What is sintering?

Sintering is a thermal process of converting loose fine particles into a solid coherent mass by heat and/or pressure without fully melting the particles to the point of melting.

Why is sintering done and why is it important?

Sintering is done to impart strength and integrity to a material as well as reducing porosity and enhancing electrical conductivity, translucency and thermal conductivity.

Which type of materials can be used for sintering?

1. **Iron and Carbon Steels**
2. **Iron-Copper and Copper Steels**
3. **Iron-Nickel and Nickel Steels**
4. **Low Alloy Steels**
5. **Sintered Hardened Steels**
6. **Diffusion Alloyed Steels**
7. **Copper Infiltrated Steels**
8. **300 Series Stainless Steel**
9. **400 Series Stainless Steels**
10. **Soft Magnetic Alloys**
11. **Copper and Copper Alloys**

What are the types of sintering process?

Sintering processes can be divided into two types:

1. **Solid state sintering**

   Solid state sintering occurs when the powder compact is densified wholly in a solid state at the sintering temperature

2. **Liquid phase sintering.**

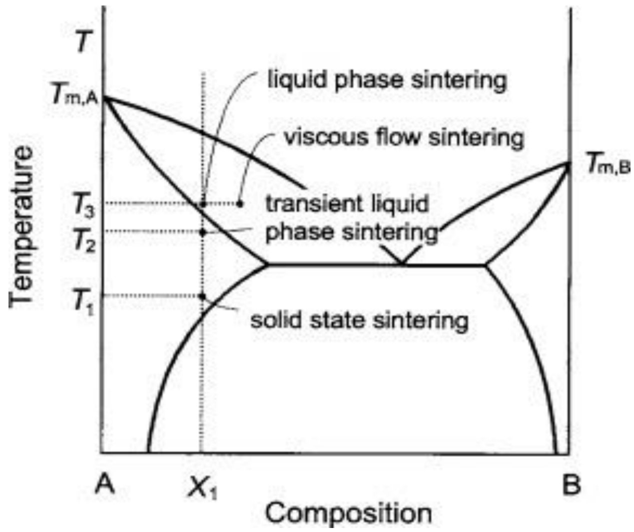
   Liquid phase sintering occurs when a liquid phase is present in the powder compact during sintering.

3. **Transient liquid phase sintering**

Transient liquid phase sintering is a combination of liquid phase sintering and solid state sintering.

4. **Viscous flow sintering**

Viscous flow sintering occurs when the volume fraction of liquid is sufficiently high.



What are steps of sintering process?

China Savvy's metal sintering process, also commonly known as the powder metallurgy process, is divided into three main steps:

I. **Blending**

- The process starts with the blending of powdered metals. To the iron based powder mix, alloying elements, additives and solid lubricant are added to the mix.
- This lubricant is needed in order to reduce the friction between the powder mass and the surface of the tool used for compaction.
- Blending in the powder metallurgy process enables the creation of a uniform mixture.

II. **Compaction**

- A filling shoe is used to deliver the powder metal to the cavity of the die and then compacted with a force of between 400 MPa to 800MPa.

III. **Sintering**

- Sintering is usually performed on a belt conveyor furnace in a controlled atmosphere.
- Parts are heated in the furnace to a temperature that is below the melting point of the main powdered metals used in the blending step of the process.

- During the sintering process, the powder grains of the ‘green’ part grow together through a diffusion process and bonds, resulting in an improvement in the part’s mechanical properties.

UNIT – 2 / HEAT TREATMENT

PART: A

1.Define heat treatment process? Give its purpose.

Heat treatment process may be defined as an operation or combination of operation involving heating and cooling of a metal/alloy in the solid state to obtain desirable properties.

purpose of heat treatment process

To relieve internal stress.
To improve machinability.
To improve hardness of the metal surface.
To increase resistance to wear, heat and corrosion

2. List any two factors that affect hardenability of steels.

Composition of steel
Critical cooling rate
Presence of alloying element
Presence of complex carbides
Homogeneity of austenite

3. What is mar tempering?

Mar tempering, also known as mar quenching, is a interrupted cooling procedure used for steels to minimize the stresses, distortion and cracking of steels the may be develop during rapid quenching.

4. What is quenching?

Quenching refers accelerated cooling. The cooling can be accomplished by contact with a quenching medium which may be a gas, liquid or solid. Most of the times, liquid quenching media is widely used to achieve rapid cooling.

5. What are the different processes of surface hardening? [N/D’15]

DIFFUSION METHODS

i. Carburizing
ii. Nitriding
iii. Cyaniding
iv. Carbonitriding

THERMAL METHODS

Flame hardening, Induction hardening, Plasma hardening, Vacuum hardening

6.What is meant by recrystallisation?

Recrystallisation is a process by which distorted grains of cold-worked metal are replaced by new, strain-free grains during heating above a specific minimum temperature.

7. Differentiate carburizing and nitriding.

Carburizing, or carburization is a heat treatment process in which iron or steel absorbs carbon liberated when the metal is heated in the presence of a carbon bearing material, such as charcoal or carbon monoxide, with the intent of making the metal harder.

Nitriding is a heat treating process that diffuses nitrogen into the surface of a metal to create a case-hardened surface. These processes are most commonly used on low-carbon, low-alloy steels.

8.What are the types of heat treatment process?

Annealing 2. Normalizing 3. Hardening 4. Tempering 5. Aus tempering 6. Mar tempering Case hardening

9. What do you mean by the term case hardening?

In many applications, it is desirable that the surfaces of the components should have high hardness, while the core or inside should be soft the treatments given to the steel to achieve this is called case hardening.

10. List any two factors that affect hardenability of steels.

Grain Size and Chemical Composition

11. What is austempering? [A/M'15]

Austempering is a type of interrupted quenching that forms bainite structure. It is an isothermal heat treatment process used to reduce quenching distortion and to make a tough and strong steel.

12. Differentiate Annealing and normalizing [A/M'15]

Annealing	normalising
Cooling is established in the furnace	Cooling is done in still air
Provides coarse grain structure	Provides fine grain structure
Temperature is lower than normalising temperature	Temperature is higher than annealing temperature
Process is costly	Process is economical

13. What is sintering?

Sintering is a thermal process of converting loose fine particles into a solid coherent mass by heat and/or pressure without fully melting the particles to the point of melting.

14. Why is sintering done and why is it important?

Sintering is done to impart strength and integrity to a material as well as reducing porosity and enhancing electrical conductivity, translucency and thermal conductivity.

15. Which type of materials can be used for sintering?

1. Iron and Carbon Steels
2. Iron-Copper and Copper Steels
3. Iron-Nickel and Nickel Steels
4. Low Alloy Steels

16. What are the types of sintering process?

1. Solid state sintering
2. Liquid phase sintering.
3. Transient liquid phase sintering
4. Viscous flow sintering

Part B

1. Write an explanatory note on annealing.
2. Write short notes stress relief annealing, recrystallization annealing and stress relief annealing.
3. Discuss the method of constructing isothermal diagrams. {APRIL/MAY 2011}
4. Explain the procedure of Jominy end quench test. (A/M 009,2011,2013)
5. Explain Case hardening.
6. Explain vacuum hardening and plasma hardening.
7. Explain induction hardening and flame hardening.
8. Explain the importance and construction of CCT diagrams.
9. Write notes on thermochemical treatment of steel.
10. What is sintering? Explain the process of sintering.