5. **Cooling Curve 5:**

Cooling curve 5, typical of an intermediate cooling rate, and austenite will start to transform to fine pearlite from$\mathbf{x_5}$. 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.

(What is critical cooling rate? Give its importance.)

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

(Explain about CCT diagrams.)

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

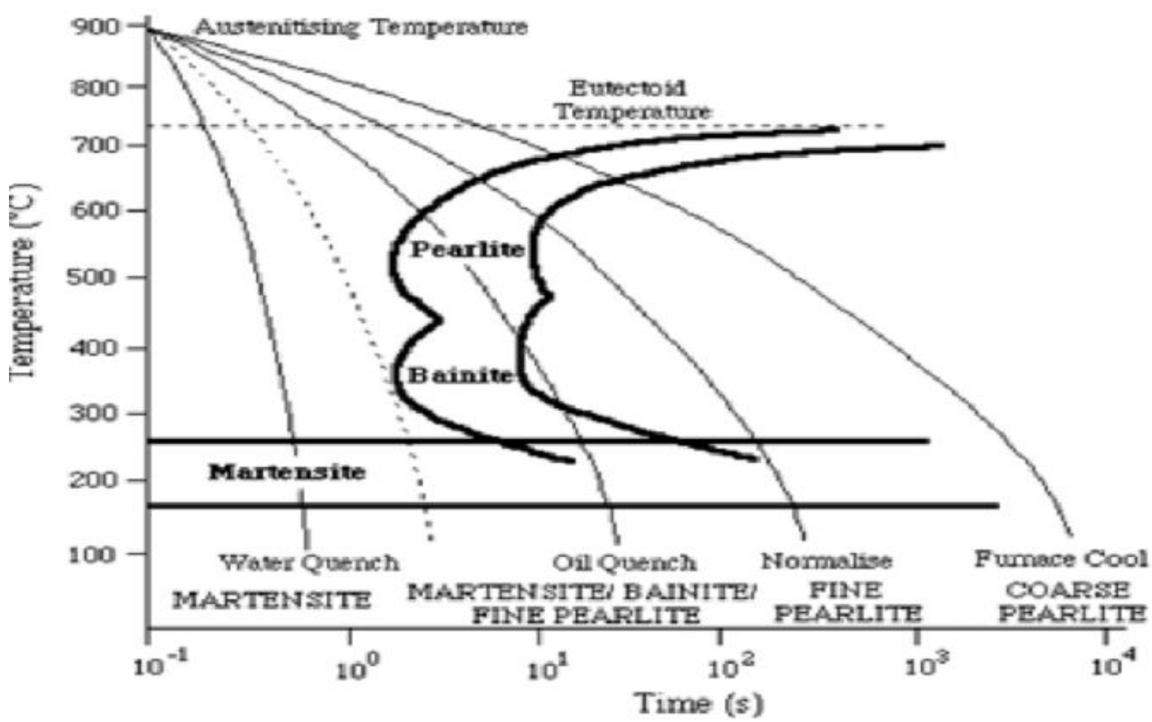
- TTT diagrams examine the progress of transformation as a function of time, at a fixed temperature.
- CCT diagrams examine the progress of transformation as a function of changing temperature**.**

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.**

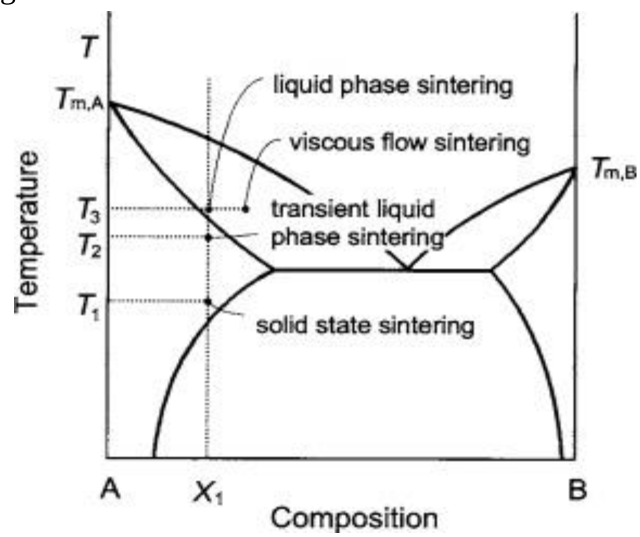
    Liquid phase sintering occurs when a liquid phase is present in the powder compact during sintering.

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?
8. What are the types of heat treatment processes?

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.