Chapter - 1

Engineering materials and their properties

* Classification of Engg. materials with their properties.

* Selection of metarials for engineering purpose.

* Physical properties of metals. Mechanical properties of metals.

* Ferrous metals - Cast Iron - Types of cast Iron - Alloy cast iron. Effect of impurities of cast iron.

* Steel - Effect of impurities on steel - Alloy steels. Stainless steel - Type of stainless steel.

* Non - ferrous metals - Types - Aluminum - Aluminum alloys.

* Copper - Copper Alloys, types. Bearing metals - Types, properties.

* Non-metallic Materials - Rubber, glass, ceramics, polymers, composite materials - properties and application of each.

* Heat treatment - Aim of heat treatment. Heat treatment technique. (Daigram)

* Annealing and its types. Normalising, hardening, tempering. (Daigram)

* Martempering, austempering, hardenability. surface hardening (Daigram)

* Carburizing, nitriding, cyaniding, flame hardening and induction hardening.

Notes

Classification of Engg. matarial with properties

* Engg. matarials can be classified into broad catogries.

1. Metals
2. Non-metals

(a) Metals

→ They most mostly opaque, hard, heavy, ductile, lustre.

→ They are good conductor of heat and electricity.

Alloy are obtained by mixing or melting two or more metals in order to improve properties of materials.

⊙ Metal can be classified into ~~two~~ 7 catogries :-

1. Ferrous
2. Non - Ferrous
3. Polymers.
4. Ceramics
5. Composites
6. Alloys
7. Smart material
8. Natural materi

1. Ferrous - Ferrous (Iron (II)) refers to the element iron in its +2 oxidation state.
It can mainly classified into three catogries :-
1. Cast Iron
2. Wrought Iron
3. Steel

1. Cast Iron - It can be classified into four types :-
i) Gray cast Iron
ii) White Cast Iron
iii) Malleable
iv) Nodular / Ductile cast Iron.

3. Steel - It can be classified into four types.
i) Low carbon
ii) Medium Carbon
iii) High Carbon
iv) Alloy.

~~2. Non-ferrous - Non-metals are the materials that is typically hard, opaque, shiny and has good electrical and thermal conductivity~~

2. **Non-ferrous metals** - It contains little or no iron. These are not magnetic and usually give more resistance to corrosion than ferrous metals.
   Eg :- Aluminium, Copper, Zinc, Lead, Tin, gold etc.

⊙ Non-Metals

Non-metals are the materials that are soft, dull and has poor electrical and thermal conductivity.
It breaks down into powder form when tapped with a hammer.
Eg :- Sulphur, Carbon, Oxygen, phosphorus etc.

☆ Difference between Metals and Non-metals :

Metals	Non-metals
i) Metals are good conductor of heat & electricity.	i) Non-metals are bad conductor of heat & electricity

ii) Metals are malleable that is they can be beaten into sheets.	ii) Non-metals are not malleable.
iii) Metals are ductline that is they can be beaten into sheets.	iii) Non-metals are non ductile.
iv) Metals are sonorous	iv) Non-metals are not sonorous.
v) Metals have high density.	v) Non-metals have low density.
vi) Metals combine with oxygen and forms basic oxides.	vi) Non-metals combine with oxygen and form acidic oxides.
vii) Metals have high melting points.	vii) Non-metals have low melting & boiling point

3. Polymers (Plastics)

i) Thermoplastics - Materials that can be melted & reformed multiple times (e.g. PVC, polystyrene, polyethylene).

ii) Thermosetting plastics - Harden permanently after being heated and shape (e.g. bakelite epoxy)

iii) Elastomers (Rubbers) - Can be stretched and return to their original shape (e.g. natur rubber, synthetic rubber & neoprene).

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4. 8. Ceramics -

i) Traditional Ceramics - Made from clay & other natural materials, used in pottery, bricks and tiles.

ii) Advanced ceramics - Include materials such as silicon carbide and alumina, often used for their hardness, heat resistance, and electrical insulating properties.

5. Composites - Materials made from two or more different substance, which, when combined, provide properties superior to those of individual materials.

i) Fiberglass - A composite of glass fiber and a resin matrix.

ii) Carbon Fiber Reinforced polymers (CFRP Light & Strong, used in high-performance applications like aerospa

iii) Metal Matrix Composites (MMC) - Combining metals with reinforcing materials like ceramics to improve properties such as strength & wear resistance.

6. Alloys -

i) Solid solutions - Mixtures of metals that are uniform in composition (e.g. brass, bronze).

ii) Interstitial Alloys - Where similar atoms fits into the space (interstices) between the larger metal atoms (e.g. steel)

iii) Precipitation - Hardening Alloys - Alloys that can be hardened by heat treatment, like aluminum alloys used in aerospace.

7. Smart Materials - Materials that respond to changes in their environment, such as temperature, pressure, or electric/magnetic fields.

i) Shape Memory Alloys (SMAs) - Material like nitinol that can return to their original shape when heated.

ii) Piezoelectric Materials - Materials that generates an electric charge in response to mechanical stress (e.g. quartz).

7. Natural Materials - Materials that are derived from nature and include wood, stone, and bamboo, among others. They

are less commonly used in advanced engineering but still important in construction $ design.

Category	Subcategory Examples	Key Properties
Metals	Steel, Cast Iron, Aluminum copper	Strength, ducti conductivity
Polymers	Thermoplastics, Thermosets, elastomers	Lightweight, flexible, insulating
Ceramics	Procelain, brick, silicon carbide	Hard, heat resistant, brittle
Composite	Fiberglass, CFRP, MMC	Lightweight, stre corrosion resista
Alloys	Brass, bronze, Stainless steel	Improved strengt Hardness, corrosion resistance
Smart Materials	Shape memory, Alloys, piezoelectric	Responsive to environmental cha
Natural materials	Wood, stone, bamboo	Biodegradable, renewable, natu appearance

Selection of Material for engineering purpose

1. The fields of application of a particular engineering materials are governed by the characteristics & various properties of the engineering materials.
Such properties are classified into various categories as follows:-

1. Mechanical properties - Consider the need for strength, hardness, ductility, toughness, and fatigue resistance.
For example, materials for lod-bearing structures need to be strong & tough.

2. Thermal properties - ~~Evalute~~ ~~thermal~~ The knowledge of thermal properties of the materia like specific heat, thermal expansion and conductivity is helpful in knowing the respons of the material to the thermal changes.

3. Electrical properties - Consider electrical conductivity or insulation properties. Materials like copper are used in electrical conductors, while other may be chosen for their insulating properties.

4. Chemical properties - Assess the material resistance to corrasion, oxidation, or

other chemical reactions, especially for materials exposed to harsh environment (e.g. in chemical plants, marine applications).

5. Environmental conditions – Consider exposure to moisture, UV radiation, or extreme environmental conditions, which could affect material performance over time.

~~2. Material Types:-~~

2. <u>Key Material properties to consider:-</u>

i) Strength – Materials must withstand the forces they'll experience without breaking.

ii) Hardness – Resistance to scratching an wear, importeint for tooling and cutting components.

iii) Ductility – Ability to stretch or ben without breaking, important for forming and shaping materials.

iv) Toughness – Ability to absorb energy without fracturing, especially under impact.

v) Corrosion Resistance - Materials must resist degradation in certain environments, such as salt water or acidic conditions.

vi) Fatigue Resistance - The material must withstand repeated loading cycles without failure, especially for high-stress and like engines or machinery

vii) Cost - Budget considerations may limit the selection of materials. Materials need to provide value for the intended application

3. <u>Processing Considerations</u> :-

i) Ease of Manufacturing - Some materials are easier to form and shape than others, influencing production time and costs.

ii) Weldability and Joining Methods - Some materials may be difficult to weld or bond, which can affect the design process.

iii) Recyclability - For sustainable design, consider materials that are recycleable or have low environmental impact.

Physical properties of metal

Metals have several distinct physical properties, including:

1. Malleability - Metals can be hammered or pressed into thin sheets without breaking.

2. Ductility - Metals can be drawn into wires without breaking.

3. High Density - Metals generally have high mass per unit volume.

4. Good condictivity - Metals are excellent conductors of heat and electricity.

5. Luster - Metals typically have a shiny appearance when polished.

6. High melting and boiling points - Ma metals have high melting and boiling points.

7. Hardness - Some metals are hard ar resistant to ~~set~~ scratching, through this varies by metals.

8. Sonorous - Metals produce a ringing sound when struck.

→ These properties vary somewhat depending on the specific metal in question, but they are common characteristics of metal in general.

Mechanical properities of metal

The mechanical properties of metals refer to their behaviour under various forces and conditions. Key mechanical properties are :-

1. Strength - The ability of a metal to resist deformation or fracture when subjected to force. It can be classified into:-

⊙ Tensile strength - The ~~ability of a meta to resist deformation~~ resistance to stretching or pulling forces.

⊙ Compressive strength - Resistance to squeezing or crushing forces.

⊙ Shear strength - Resistance to forces that causes sliding or shearing along a a plane.

2. Hardness - The ability of metal to resist ~~st~~ scratching, identation, or surface deformation. It indicates how well a metal can withstand external forces.

3. Elasticity - The ability of a metal to return to its original shape after ~~beig~~ being deformed by stress (within the elastic limit).
This is the property that defines how well a metal can bend or stretch and then return to its original form.

4. Plasticity - The ability of a metal to undergo permanent deformation without breaking. When a metal is beyond its elastic limit, it deforms plastically

5. Toughness - The ability of a metal to ~~undergo permanent Deforma~~ absorb energy and withstand fracturing. A tough metal can endure significant deformation before breaking.

6. Fatigue Resistance - The ability of a metal to withstand repeated loading and unloading cycles without failing. This property is crucial for materials used in structures that experience continuous stress, like in engines or aircraft.

7. Creep - The gradual deformation of a metal under constant stress over time, particularly at high temperatures.

→ 8 These machanical properties are vital for determining how metals are used in various applications, from construction to aerospace engineering.

Ferrous Metals and cast Iron

Ferrous metals are metals primarily composed of iron. They often contain varying amounts of carbon and other elements, making them suitable for various applications due to their strength and versatility.
Cast iron is one of the most common forms of ferrous metals.

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*** → Types of cast Iron

Cast iron is iron that has been melted and poured into moulds to form a solid structure. The main types of cast iron are :

1. Gray Cast Iron :
- Contains carbon in the form of graphite flakes.
- Known for its excellent castability, machinability, and damping characteristics.
- Used for engine, pipes, and machinery components.

2. White Cast Iron :
- Contains carbon in the form of camentite (iron carbide), which is hard and brittle.
- Has a white fracture surface.
- Used in applications where hardness is required, such as in wear-resistan parts.

3. Ductile (Nodular) Cast Iron :
- Contains small amounts of magnesium, which causes the carbon to form spherical graphite nodules rather than flakes.

- Offers good strength, ductility, and toughness.
- Used in automotive components and machinery.

4. Malleable cast Iron:
- Produced by heat-treating white cast iron to produce a structure that is more malleable.
- It is tough and used for parts like fittings and hardware.

5. Alloy cast Iron:
- This is cast iron that has had alloying element (such as nickel, chromium, molybdenum, or copper) added to improve specific properties.
- These can improve corrosion resistance, wear resistance, or high-temperature strength.
- Examples includes high-chromium cast iron for abrasion resistance or nickel cast iron for heat resistance.

Alloy cast Iron

Alloy cast Iron refers to cast iron that has additional alloying elements added to improve its properties for specialized

application.
Common alloying elements include:

- Nickel - Increases toughness and resistance to oxidation and corrosion.

- Chromium - Improves hardness, abrasion resistance, and corrosion resistance.

- Molybdenum - Enhances strength at high temperatures and improves wear resistance.

- Copper - Improves corrosion resistance and increases strength.

** # Effect of Impurities on cast Iron

Impurities can have significant effects on the properties and quality of cast iron.
These can include:-

1. Sulfur -

→ Sulfur can form iron sulfide (FeS), which is brittle and reduces the overall strength and ductility of cast iron.

→ It can also affects machinability

and surface finish.

2. Phosphorus - Phosphorus ~~incl~~ increases the fluidity of the molten iron but makes the material more brittle, reducing its toughness.

- High phosphorus content can cause cast iron to be more prone to facture under stress.

3. Oxygen -

- Oxygen can forms oxides in cast iron, affecting its intergrity and causing surface defects.
- High oxygen content can decrease strength and increase brittleness.

4. Silicon -

- Silicon is a desirable impurity in cast iron, as it enhances fluidity and helps to control the formation of graphite, contributing to a smoother casting process.
- However, too much silicon can cause ~~exp~~ excessive formation of graphite and lead to poor mechanical properties.

6. Carbon -

- While carbon is a primary element in cast iron, excessive amounts can make the iron excessively brittle or prone to cracking.

- The form in which carbon exists (graphite vs cementite) greatly affects the mechanical properties of the cast iron.

→ In conclusion, while certain impurities are unavoidable, controlling their levels is essential for producing high-quality cast iron with the desired mechanical properties. Proper alloying and purification processes are necessary to mitigate the ~~effe~~ effect of impurities.

Steels

Steel is an alloy primarily composed of iron and carbon, with varying amounts of other elements such as manganese, chromium, nickel and venadium to improve its properties

→ Key characteristics of steel :

1. Strength
2. Ductility
3. Toughness
4. Corrosion resistance
5. Weldability

→ Types of Steel
1. Carbon steel
2. Alloy steel
3. Stainless steel
4. Tool steel
5. High - speed steel
6. Structural Steel

Impurities and their Effect on steel :-

Impurities can have a significant impact on the properties of steel. They are usually unwanted elements that are present in trace amounts during the steel production process. The main impurities found in steel include sulfur, phosphorus, oxygen, nitrogen, and carbon. Their effects include :

1. Sulfur - It can lead to brittleness in steel, especially at high temperature, causing a phenomenon known as "hot shortness".
This makes the steel less ductile and more prone to cracking during hot working processes like forging.

2. Phosphorus - This impurity reduces steel's thoughness and ductility, particularly a

lower temperatures. High phosphorus content can make steel brittle, a problem known as "cold shortness".

3. Oxygen - Oxygen can form oxides in steel, weakening its structure and making it more prone to corrosion. It also affects the strength and durability of the steel.

4. Nitrogen - Nitrogen can enhance the strength and hardness of steel but may reduce its workability. In stainless steels, however, nitrogen is used deliberately in controlled amounts to improve corrosion resistance.

5. Carbon - Carbon is a major alloying element in steel. The amount of carbon in steel determines its hardness, strength and ductility. Too much carbon, however, can make the steel too brittle.

Alloy Steel

Alloy steel are steels that contains other elements in addition to carbon, such as chromium, nickel, venadium or molybdenum.

These additional elements are added to improve specific properties, such as:

- Strength
- Corrosion resistance
- Toughness

Common alloy steel include:

- Chromium steel
- Nickel steel
- Manganese steel
- Tool steels

*** # Stainless Steel:

1. Austenitic stainless steel
- Composition: Primarily iron, chromium (16 - 26%), and nickel (6 - 22%).
- Properties: High corrosion, resistance, good formability and excellent weldability.
- Common grades: 304, 316 (with 316 having added molybdenum for better corrosion resistance)
- Uses: kitchen equipment, chemical processing equipment, food processing and medical devices.

2. Ferritic Stainless steel:
- Composition: Contains chromium (10.5 - 30%) but very little or no nickel.
- Properties: Magnetic, with good corrosion

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resistance and moderate strength. It's less expensive than austenitic stainless steel but lacks the toughness of austenitic grades.

- Common grades : 430, 446

- Uses : Automotive exhaust systems, appliances, and some cookware.

3. Martensitic stainless steel
- Composition - Contains higher carbon content (0.1 - 1.2%) in addition to chromium (12-18%).

- Properties : High hardness, strength, and wear resistance, but less corrosion resistance compared to austenitic and ferritic grades.

- Common grades : 410, 420, 440C.

- Uses : Cutlery, surgical instruments & value parts.

4. Duplex stainless steel :
- Composition - A mix of austenitic and ferritic stainless steel, containing around 18 - 28% chromium & 4 - 8% nickel.

- Properties - Offers a balance b/w the

strength $ toughness of ferritic steel $ the corrosion resistance of austenitic steel.

- Common Grade: 2205

- Uses: Off-shore oil rigs, chemical plants, and desalination plants.

5. Precipitation - Hardening stainless steel:
- Composition:- Contains alloying elements like aluminum, copper or titanium to enhances the strength via heat treatment processes.

- Properties: High strength; good corrosion resistance, and the ability to be hardened by heat treatment.

- Common Grades: 17-4 PH, 15-5 PH.

- Uses: Aerospace, military, and high-strength industrial applications.

☆ Non-ferrous metal - Types - Aluminium - Aluminum alloy

Non-ferrous metals are metals that do not contain significant amounts of iron, which makes them resistant to rust

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and corrosion.

→ Aluminium (Al)
Aluminum is one of the most common non-ferrous metals, and it has various alloys with distinct properties.

⊙ Properties :-
Lightweight, non-corrosive, excellent electrical and thermal conductivity, high strength-to-weight ratio.

⊙ Uses :-
Widely used in aerospace, transportation (cars, airplanes), packaging (aluminum foil), and electrical conductors.

→ Aluminum Alloys
Aluminum alloys are mixtures of aluminum with other metals like copper, magnesium, manganese, silicon and zinc. The alloying improves properties such as strength, hardness, and resistance to corrosion. They are typically ~~as~~ classified into two categories :

1. Wrought Aluminum Alloys : These are alloys that are shaped by processes such as rolling, extruding, or

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forging.

2. Cast Aluminum Alloys : These alloys are typically poured into molds to create shapes.

→ Key Advantages of Aluminum Alloys :-

- Lightweight : Ideal for applications where weight reduction is important.

- Corrosion Resistance : Most aluminum alloys are highly resistant to corrosion, especially in marine environment.

- Strength : Alloys can be engineered to meet specific strength needs.

- Recyclability : Aluminum is highly recyclable without losing its properties.

Aluminum and its alloy are integral to many industries due to their versatility and performance.

★ Copper - copper alloy, types. Bearing metals - types, properties

→ Copper and Copper Alloys

Copper (Cu) :-

Properties :

i) Excellent Electrical Conductivity
ii) Good thermal conductivity
iii) Corrosion Resistance
iv) Malleability and ductility
v) Antibacterial

Uses :

Electrical wiring, plumbing, roofing, industrial machinery, and coins.

Copper Alloys

Copper alloys are mixtures of copper and other elements, enhancing its properties like strength, hardness, corrosion resistance, or machinability.

Key copper alloys include :-

1. Brass (copper - Zinc Alloys)

Composition : Copper and zinc, with varying zinc content.

Properties :

i) Good strength and ductility.
ii) Excellent corrosion resistance especially in marine environments.
iii) Gold - like appearance

Uses : Coins, musical instruments, fittings, and decorative items.

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2. Bronze (Copper - Tin Alloys)
- Composition: Copper and tin, sometimes with other elements like phosphorus, aluminum, or silicon.

- Properties:
  i) High corrosion resistance, especially in seawater.
  ii) Hard and wear-resistant.
  iii) Low friction, making it ideal for bearings

- Uses - shipbuilding, sculptures, bearings, electrical connectors.

3. Copper - Nickel Alloys (Cu-Ni)
- Composition: Copper and nickel (usually 10-30% nickel).

- Properties:
  i) Excellent resistance to corrosion, especially in marine environments.
  ii) High strength and good thermal conductivity.

- Uses - Marine engineering, coinage, heat exchangers

4. Copper - Phosphorus Alloys:
- Composition: Copper & phosphorus

- Properties: i) Good wear resistance
  ii) Can be used in brazing materials.

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- Uses: Electrical components, brazing materials

5. Copper - Aluminum Alloy (Aluminum Bronze):
- Composition: Copper and aluminum (typically 5-12% aluminum).

- Properties:
i) Strong with good resistance to corrosion.
ii) Used in marine and aerospace applications.

- Uses: Propellers, turbine blades, marine, fittings.

→ Bearing metals - types, properties
Bearing metals are materials specifically designed for use in bearing, which are mechanical components that reduce friction and wear between moving parts. These metals are essential in applications like engines, machines, and other equipment that require smooth rotation or movement. Below are some common types of bearing metals, along with their properties:

1. Bronze Alloys (e.g Tin bronze, phosphor Bronze)
- Types: Tin bronze (CuSn), phosphor bronze (CuSnP), Aluminum bronze (CuAl)

- Properties: i) High strength and hardness
ii) Good wear resistance and low friction.

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iii) Excellent corrosion resistance
iv) Suitable for high-load, low-speed applications.
v) Offers good machinability

- Application: Used in heavy machinery, marine, and automotive applications.

2. Babbitt Metals.
- Types: Tin based babbitt (CuSn + Sb), Lead-based Babbitt (CuPb + Sn), Aluminum-based babbitt.

- Properties:
i) Excellent comformability to shaft surface.
ii) Low coefficient of friction.
iii) Good anti-wear properties.
iv) Low-melting point.

- Applications: Often used in high-speed, low-to-medium load bearings, such as in engines and motors.

3. Steel Alloys
- Types: Chromium steel, High-carbon steel, stainless steel.

- Properties: i) High hardness & strength
ii) Good resistance to wear
iii) Corrosion resistance.

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- Applications : Used in automotive engines, turbines and industrial machinery.

★★★ 4. Aluminum Alloys
- Types : Aluminum - silicon (Al - Si), Aluminum - copper (Al - Cu), Aluminum - zinc (Al - Zn)

- Properties : i) Lightweight and good strength-to-weight ratio
ii) Excellent corrosion resistance
iii) Moderate wear resistance
iv) Good thermal conductivity

- Applications : Used in light-load applications, where weight reduction is important, such as in aerospace and automotive sectors.

5. Copper Alloy
- Types : Copper - nickel (CuNi), Copper - tin (CuSn)

- Properties :
i) Good corrosion resistance, particularly in marine environments.
ii) Excellent heat conductivity
iii) Good resistance wear & high loads

- Applications : Used in marine applications, heavy-duty bearings, and high-temperature environment.

6. Lead Alloys
- Types: Lead-tin (PbSn), Lead-antimony (PbSn)

- Properties:
  i) Very low friction & good comformability
  ii) Ability to withstand heavy loads and shock.
  iii) Poor corrosion resistance (hence not ideal for all environments).

- Applications: Often used in low-speed, heavy-load bearings, such as in large turbines, and industrial machinery.

7) Properties of Ideal Bearing Metals
- Low friction
- High wear resistance
- Conformability
- Strength
- Corrosion resistance

☆ Non metallic materials - rubber, glass, ceramics, polymers, composite, ~~poly~~ material - properties and application of each

1. Rubber
Properties:
i) Elasticity
ii) Duraability

iii) ~~Dura~~bility Water resistance
iv) Electrical insulator
v) Thermal stability

Applications :
i) Automotive Industry
ii) Footwear
iii) Medical
iv) Consumer Products
v) Construction

2. Glass
Properties :
i) Transparency
ii) Brittle
iii) Heat resistance
iv) Chemical resistance
v) Electrical insulator

Applications :-
i) Construction
ii) Electronics
iii) Packaging
iv) Medical
v) Art and Decoration

3. Ceramics
Properties :
i) Hardness
ii) Brittleness

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iii) High temperature resistance
iv) Electrical insulation
v) Chemical resistance

Applications :
i) Construction
ii) Electronics
iii) Aerospace & Engineering
iv) Medical
v) Household Items

4. Polymers
Properties :
i) Lightweight
ii) Flexibility
iii) Durability
iv) Electrical insulating properties
v). Thermal insulation

Applications :
i) Packaging
ii) Textiles
iii) Medical
iv) Automotive
v) Electronics

5. Composite Materials
Properties :
i) Strength - to - weight ratio
ii) Durability

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iii) Customizability
iv) High performance

Applications:
i) Aerospace
ii) Automotive
iii) Sports Equipment
iv) Construction
v) Marine

☆☆☆☆ Heat treatment - Aim of heat treatment, Heat treatment techniques.

→ Heat treatment
Heat treatment is a process used to alter the physical and sometimes chemical properties of a materials (typically metals and alloy) through controlled heating and cooling.

→ Aim of heat treatment:
- Increase hardness and strength
- Improve ductility and toughness
- Relieve Internal stresses
- Refine Grain Structure
- Enhance Machinability

→ Heat treatment techniques:-
1. Annealing - Softening, relieving stress, improve ductility.

2. Quenching - Rapid cooling to increase hardness.
3. Tempering - Adjusting hardness and incrasing toughness.
4. Normalizing - Refining grain structure for uniform properties.
5. Hardening - Increasing hardness through rapid cooling.
6. Case hardening - Hardening the surface while maintaning a tough core.
7. Austempering - Creating a tough wear-resistant structure.
8. Spheroidizing - Making materials easier to machine by producing a soft structure.
9. Precipitation Hardening - Strengthening alloys by precipitating fine particle.
10. Induction / Laser Hardening - Surface hardening with rapid heating & cooling.

★★★ Annealing and its types. Normalising, hardening, tempering.

→ Annealing is a heat treatment process used to alter the physical and sometimes chemical properties of a material usually metal, to increase its ductility and reduce hardness.
Annealing helps to relieve internal stresses, improve machinability, and increase

the material's softness.

→ Types of Annealing :

1. Full Annealing
- This process involves heating the materials (often steel) to a high temperature, typically above the critical temperature, and then allowing it to cool slowly, usually in a furnance.

It is used to soften the materials and improve its workability.

2. Process Annealing :
- This type of annealing involves heating the material to a temperature just below the critical point, followed by cooling it at a controlled rate.

- It is often used for low-carbon steels to relieve internal stresses $ improve machinability.

3. Stress Relief Annealing :
- This is a lower temperature annealing process that is used to relieve stresses induced during previous mechanical operations (like machining or welding).

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- The material is heated to a temperature below its critical point, held for a period, and then slowly cooled.

4. Spheroidizing:
- This process is typically applied to high-carbon steels and involves having the material is a temperature just below the critical point for an extended period to allow the carbon to form spherical carbide particles

- The result is improved machinability.

Related Heat Treatment Processes:

1. Normalizing:
- Normalizing involves heating a metal, typically steel, to a temperature above its critical point and then allowing it to cool in air.

- This process refines the grain structure of the material and can enhance its strength & hardness. It's often used to improve the mechanical properties of castings and forging.

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2. Hardening :

- Hardening is the process of heating the meterial to a temperature above its critical point and then rapidly cooling it, typically in water, oil or air.

- This rapid cooling causes the material to become harder but also more brittle. It is often followed by tempering to adjust hardness and brittleness.

3. Tempering

- Tempering is typically done after hardening to reduce brittleness and increase toughness.

- It involves reheating the hardened material to a temperature below its critical point and then allowing it to cool. The temperature and duration of tempering influence the final properties, like hardness, strength, and ductility.

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★ Martempering, austempering, hardenability, surface hardening.

1. Martempering : This is a heat treatment process that involves quenching a steel component in a medium, typically molten salt or oil, at a temperature above the martensite start (Ms) temperature. The goal is to reduce the thermal gradient between the outer and inner parts of the material to avoid the formation of cracks and to obtain a more uniform microstructure, which makes the material less susceptible to stress.
After this, the material is cooled to room temperature.

2. Austempering : Austempering is a heat treatment process that involves heating the material to a temperature above the critical range and then cooling it in a medium (usually salt) to a temperature just above the martensite start temperature.
The material is held at this temperature for a period, allowing th ~~full~~ formation of a bainitic

structure, which offers a combination of good strength and toughness. This process is often used for steels and cast irons.

3. Hardeninability : This refers to the ability of a material, particularly steel, to harden when subjected to heat treatment. It is largely influenced by the chemical composition of the material, especially the carbon content, as well as its alloying elements like manganese, chromium and nickel. Materials with higher hardenability can achieve uniform hardness even in thicker sections, whereas materials with low hardenability may only be able to harden on the surface, with the core remaining softer.

4. Surface Hardening : Surface hardening is a process where only the outer layer of a material is hardened, leaving the inner core soft. This is often achieved through processes like carburizing, nitriiding, or induction hardening.

The purpose of surface hardening is to improve the wear resistance, fatigue resistance, and overall durability of a component without sacrificing its toughness and ductility, especially for parts that are subjected to high friction or stress on the surface

★ ~~Cad~~ Carburizing, nitriding, cyaniding flame hardening and induction hardening

The terms - carburizing, nitriding, cynading, flame hardening, and induction hardening - refer to various heat treatment processes used to enhance the surface hardness and wear resistance of metals, especially steel.
Here's brief explanation of each process:-

1. Carburizing
Carburizing is a process in which carbon is added to the surface of low-carbon steel by heating it in a carbonrich environment (usually in a furnance or with gas.

Purpose:-
This increases the carbon content at the surface of the steel, creating a

hardened surface while maintaing a soft more ductile core.

Common Use:
Cardburizing is typically used for parts like gears, shafts, and crankshafts, where a tough core is required but a hard, wear resistant surface is also needed

2. Nitriding
Nitriding is a process where nitrogen is introduced into the surface of a steel part, usually by heating it in ammonia gas or other nitrogen sources.

Purpose:
The nitrogen reacts with the metal to form hard nitrides, which significantly increase surface hardness, wear resistance and fatigue strength.

Common Use:
Nitriding is often used for tools, dies, and parts subjected to wear and corrosion, as it also provide excellent corrosion resistance.

3. Cynading

Cynading is a process similar to carburizing, where a steel part is exposed to a mixture of cynide salts (typically sodium ~~cyna~~ cyanide or potassium cyanide) to introduce both carbon & nitrogen into the surface of the steel.

Purpose :
This process increases the surface hardness of steel, improving wear resistance and fatigue strength.

Common Use :
It is used for parts like gears, sprockets, and small components, but due to the toxic nature of cyanide, it is less commonly used that carburizing or nitriding.

4. Flame Hardening

- Flame Hardening involves heating the surface of metal using an oxy-acetylene or oxy-propane flame & then quickly cooling it with water or air.

Purpose :
The rapid heating and cooling process hardens only the surface of the part

while leaving the interior relatively unaffected. This creates a hard, wear-resistant surface.

Common use :
Flame hardening is typically applied to large parts like rollers, crack shafts, and gears that need a hard surface for wear resistance but do not require deep hardening.

5. Induction Hardening
Induction hardening uses electromagnetic induction to heat the surface of a steel part, ~~followed~~ followed by quenching (rapid cooling, usually with water or oil).

Purpose :
The induction process hardens only the surface of the part, leaving the core material unaffected. This is controlled by adjusting the depth of the heat and the quenching method.

Common use :
Induction hardening is used for components like shafts, gears, and other parts that need surface hardening with a tough core.