

Basic Mechanical Engineering of BCME Subject

UNIT I

A. Introduction to Mechanical Engineering:

Mechanical engineering is the discipline that applies engineering, physics and materials science principles to design, analyse, manufacture and maintain mechanical systems. It is one of the oldest and broadest of the engineering disciplines.

It deals with the various engineering fields of Automobile, Steel, Cement industry, Power sector, Manufacturing plants, Hydraulics, Drilling and Mining industry, Robotics, Thermal sciences, Aeronautical, Petroleum, Biotechnology, Generators, internal combustion engines, steam and gas turbines as well as power using machines such as refrigeration and air-conditioning systems etc.

Role of a Mechanical Engineer in our society and in Industries

Mechanical engineers are involved in almost every aspect of human existence and welfare, including machines, cars and other vehicles, aircraft, power plants, automobile parts, and manufacturing plants etc. It also includes systems that are essential to many aspects of modern society and Industries. They use their knowledge of mechanics, thermodynamics, materials science, and energy to create solutions that improve the quality of life of people.

They may also work on projects related to energy conservation, sustainability, and renewable energy sources for environmental protection. They contribute to society by using their skills to improve the safety, security, efficiency, and comfort of the systems and devices that we rely on every day.

The role of a mechanical engineer in Industry and society is contributed as:

Industry:

1. Product Design and Development:

- Mechanical engineers are involved in the design and development of products, ensuring they meet performance, safety, and cost requirements.

2. Manufacturing and Production:

- They optimize manufacturing processes, implement quality control measures, and work on cost-effective production methods.

3. Materials Selection and Testing:

- Mechanical engineers choose appropriate materials for products and conduct tests to ensure their suitability and performance.

4. Process Engineering:

- They design and optimize processes to improve efficiency in manufacturing and other industrial operations.

5. Quality Assurance and Control:

- Mechanical engineers play a vital role in maintaining and improving product quality, implementing quality control measures throughout the production process.

6. Maintenance and Reliability:

- They contribute to the maintenance of machinery and equipment, ensuring they operate efficiently and safely.

7. Energy Systems and Sustainability:

- Mechanical engineers work on designing and improving energy systems, with a growing focus on sustainability and renewable energy sources.

8. Automation and Robotics:

- They design and implement automated systems, improving efficiency and precision in manufacturing and other industrial processes.

9. Project Management:

- Many mechanical engineers take on leadership roles, overseeing projects, managing teams, and ensuring projects are completed on time and within budget.

10. Research and Development:

- Mechanical engineers engage in research to develop new technologies, materials, and processes that can enhance product performance and competitiveness.

Society:

1. Infrastructure Development:

- Mechanical engineers contribute to the design and construction of critical infrastructure such as buildings, bridges, and transportation systems.

2. Environmental Impact:

- They work on developing technologies and practices that minimize the environmental impact of industrial processes and products.

3. Healthcare and Biomedical Engineering:

- Mechanical engineers contribute to the development of medical devices, prosthetics, and other healthcare technologies, improving the quality of life for individuals.

4. Automotive Safety:

- They play a key role in designing and implementing safety features in automobiles, reducing the risk of accidents and injuries.

5. Disaster Response and Recovery:

- Mechanical engineers contribute to the development of technologies and systems used in disaster response, including rescue equipment and emergency shelters.

6. Education and Research:

- Mechanical engineers often contribute to education and research institutions, passing on knowledge and contributing to advancements in the field.

MECHANICAL ENGINEERING TECHNOLOGIES

Mechanical engineering technologies play a crucial role in various sectors, including energy, Manufacturing, Automotive, Aerospace and Marine Engineering.

In all these sectors, computer-aided design (CAD), finite element analysis (FEA), and simulation tools play a crucial role in product development and optimization. Mechanical engineers collaborate with experts in materials science, electronics, and control systems to create innovative solutions that meet the specific challenges and requirements of each industry.

Mechanical engineering technologies role in Energy sector:

Here are some examples of how mechanical engineering technologies are applied in different energy-related sectors:

1. **Renewable Energy:** Renewable energy is energy produced from sources like the sun and wind that are naturally replenished and do not run out. Renewable energy can be used for electricity generation, space and water heating and cooling, and transportation.
 - **Wind Energy:** Mechanical engineers design and optimize wind turbine systems. They work on blade design, gearbox efficiency, and tower structures to maximize energy conversion and minimize maintenance.
 - **Solar Energy:** They design solar panels, focusing on materials, heat management, and tracking systems to improve energy capture and conversion.
 - **Hydropower:** They work on the design and maintenance of hydroelectric turbines and dams to harness the power of flowing water.
2. **Fossil Fuels:** Fossil fuels such as Coal, Oil and Gas are some of the most important natural resources that we use every day. These fossil fuels are all Hydrocarbons, they are compounds formed from only two elements, Carbon and Hydrogen.
 - **Power Plants:** They are involved in the design, maintenance, and optimization of various types of power plants, such as coal, natural gas, and oil-fired plants.
 - **Oil and Gas:** They design drilling equipment, pipelines, and refining processes to extract, transport, and refine fossil fuels efficiently and safely.
3. **Nuclear Energy:** They play a crucial role in the design and maintenance of nuclear power plants, focusing on reactor components, cooling systems, and safety protocols.
4. **Energy Storage:** They contribute to the development of energy storage technologies, such as advanced batteries, compressed air energy storage, and flywheel systems.
5. **Transmission and Distribution:** In the electric power sector, mechanical engineers are involved in the design and maintenance of high-voltage transmission lines, transformers, and distribution systems.
6. **Energy Efficiency:** They work on improving energy efficiency in various sectors by designing more energy-efficient HVAC systems, industrial machinery, and appliances.

HVAC stands for heating, ventilation, and air conditioning. It refers to the systems that regulate and move heated and cooled air throughout residential and commercial buildings, from homes to offices to indoor stadiums.

7. **Automotive Industry:** They play a role in the development of energy-efficient vehicles, including hybrid and electric cars, by optimizing engine designs and aerodynamics.
8. **Aerospace:** In the aerospace sector, mechanical engineers work on developing more fuel-efficient aircraft and spacecraft by optimizing engine performance and materials.
9. **Marine and Offshore Engineering:** In the offshore sector, mechanical engineers design and maintain offshore wind turbines, oil rigs, and other structures used in energy production.
10. **Geothermal Energy:** They are involved in the design and maintenance of geothermal power plants and heat exchangers used in geothermal heating and cooling systems.
11. **Bioenergy:** In the bioenergy sector, mechanical engineers work on the design of biomass processing equipment, such as boilers and gasifiers, used for energy generation from organic materials.

Mechanical engineering technologies role in Manufacturing sector:

Here are some key ways in which mechanical engineering technologies are applied in the manufacturing sector:

1. **CNC Machining:** Computer Numerical Control (CNC) machining uses computer programs to control machining tools and equipment. This technology allows for precise and automated manufacturing processes, enabling the production of complex parts and components with high accuracy.
2. **Additive Manufacturing (3D Printing):** Additive manufacturing technologies, such as 3D printing, have revolutionized manufacturing by allowing for rapid prototyping, customization, and the creation of complex geometries that would be difficult to achieve with traditional manufacturing methods.
3. **Robotics and Automation:** Mechanical engineers design and implement robots and automated systems for tasks like material handling, assembly, and quality control. These technologies improve efficiency, reduce labor costs, and enhance product consistency.
4. **Materials Science:** Mechanical engineers work with materials scientists to develop and select materials with specific properties for various manufacturing processes. This includes optimizing material strength, durability, and heat resistance.
5. **Quality Control and Inspection:** Mechanical engineers design and develop inspection systems that use technologies like machine vision and sensors to ensure product quality and detect defects during the manufacturing process.
6. **CAD/CAM Software:** Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software are essential tools in modern manufacturing. These

software packages enable engineers to create 3D models of products and generate toolpaths for machining and manufacturing processes.

7. **Finite Element Analysis (FEA):** FEA software helps mechanical engineers simulate and analyze how products and components will perform under various conditions. This technology is crucial for optimizing designs and ensuring product safety.
8. **Lean Manufacturing:** Mechanical engineers often contribute to the implementation of lean manufacturing principles, which focus on eliminating waste, reducing costs, and improving production efficiency.
9. **Energy Efficiency:** Mechanical engineers work on improving the energy efficiency of manufacturing processes and equipment, contributing to sustainability efforts and reducing environmental impact.
10. **Supply Chain Management:** Mechanical engineers may also be involved in supply chain management, optimizing the flow of materials and products from suppliers to manufacturers and ultimately to customers.
11. **Robot-Assisted Welding:** In industries like automotive and aerospace, robot-assisted welding systems are used to ensure precise and high-quality welds, improving structural integrity and reducing production time.
12. **Advanced Manufacturing Techniques:** This includes technologies like laser cutting, waterjet cutting, and abrasive machining, which provide more precise and efficient ways to shape and fabricate materials.

Mechanical engineering technologies role in Automotive Engineering sector:

It is a branch study of engineering which teaches manufacturing designing, mechanical mechanisms as well operations of automobiles. It is an introduction to vehicle engineering which deals with motorcycles, cars, buses trucks etc. It includes branch study of mechanical, electronics, software and safety elements.

Mechanical engineering technologies play a critical role in Automotive Engineering.

1. **Advanced Materials:** Automotive engineers work with a wide range of materials, including lightweight composites, aluminum, high-strength steel, and carbon fiber, to improve fuel efficiency and safety while reducing weight of automobiles
2. **Engine Technology:** Development of efficient and eco-friendly engines, such as electric and hybrid powertrains, as well as advanced combustion engines and turbocharging.
3. **Vehicle Dynamics:** Technologies like active suspension systems, electronic stability control, and anti-lock braking systems (ABS) enhance vehicle handling and safety.
4. **Autonomous Vehicles:** Mechanical engineers are involved in the design and development of components for self-driving cars, including sensors, actuators, and control systems.
5. **Manufacturing and Production:** Automation, robotics, and advanced manufacturing techniques are used to improve production efficiency and quality.

Mechanical engineering technologies role in Aerospace Engineering sector:

Aerospace engineering is the primary field of engineering concerned with the design, development, testing, and production of aircraft, spacecraft, and related systems and equipment.

Mechanical engineering technologies play a critical role in Aerospace Engineering.

1. **Aerodynamics:** Engineers use computational fluid dynamics (CFD) simulations and wind tunnel testing to optimize aircraft designs for aerodynamic efficiency and performance.
2. **Structural Analysis:** Aerospace engineers design and analyze lightweight, high-strength materials and structures to ensure the structural integrity and safety of aircraft and spacecraft.
3. **Propulsion Systems:** Development of jet engines, rocket propulsion systems, and innovative propulsion technologies for greater efficiency and power.
4. **Avionics:** Integration of advanced electronics, sensors, and control systems for navigation, communication, and safety in aircraft and spacecraft.
5. **Space Exploration:** Mechanical engineers are involved in the design of space exploration vehicles, such as rovers and spacecraft, to withstand extreme conditions in outer space.

Mechanical engineering technologies role in Marine Engineering sector:

Marine Engineering is the discipline that deals with matters related to the design, innovation, construction and maintenance of seagoing vessels and navigation equipment. Marine Engineering focuses primarily on the development and production of internal systems of boats, ships, or submarines.

Marine Engineering is closely related to other fields such as naval architecture, nautical sciences, oceanographic engineering, or automotive and mechanical engineering. These study areas require very good knowledge of physics, and more specifically fluid mechanics, propulsion, applied mathematics, control engineering, and computer-aided design (CAD).

Mechanical engineering technologies play a critical role in Marine Engineering

1. **Ship Design and Naval Architecture:** Mechanical engineers are involved in designing ships and naval vessels, optimizing hull shapes, and ensuring stability and performance in various sea conditions.
2. **Propulsion Systems:** Development of efficient and eco-friendly marine propulsion systems, including diesel engines, gas turbines, and electric propulsion for ships and submarines.
3. **Fluid Dynamics:** Analysis of fluid flow around ships to reduce drag and improve fuel efficiency.

4. Offshore Engineering: Mechanical engineers work on offshore platforms, subsea equipment, and underwater robotics for offshore oil and gas exploration, renewable energy generation, and underwater research.
 5. Marine Safety: Design and implementation of safety systems, including life-saving equipment, fire suppression systems, and structural integrity measures for marine vessels.
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B) Engineering Materials

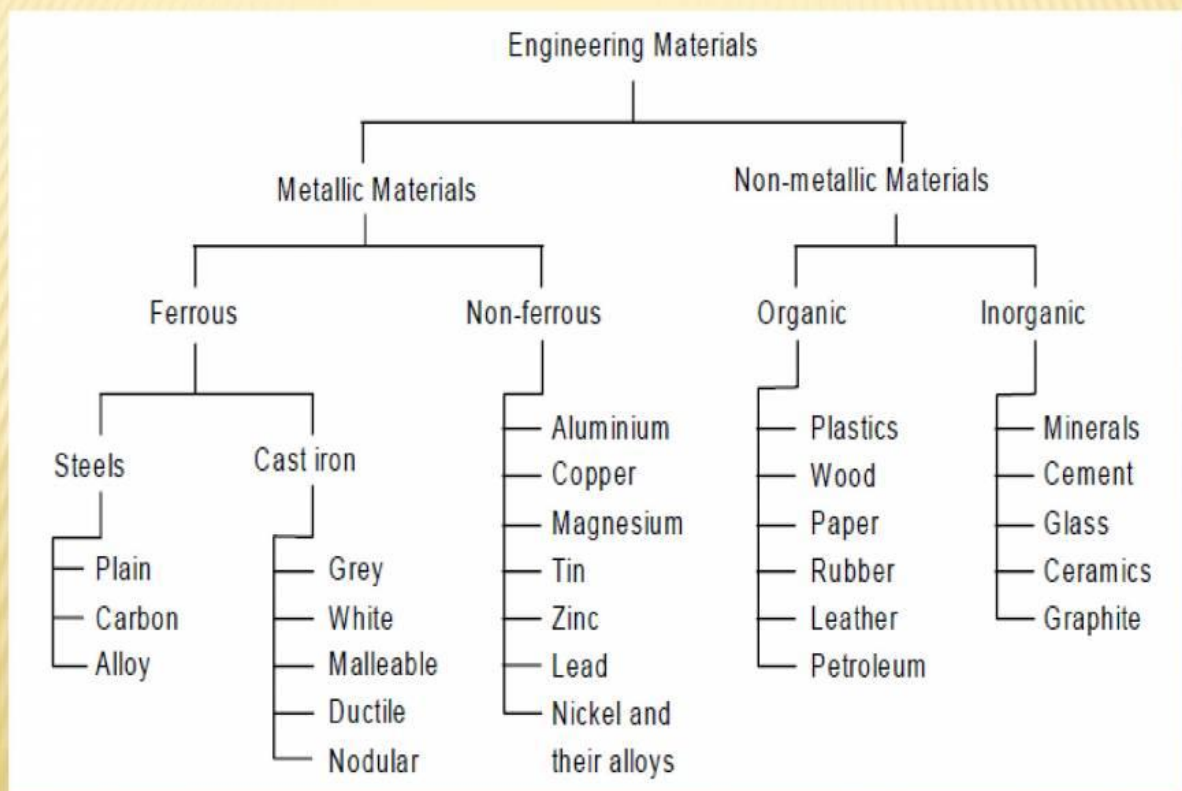
Engineering materials refers to the group of materials that are used in the construction of manmade structures and components.

The primary function of an engineering material is to withstand applied loading without breaking and without exhibiting excessive deflection.

The engineering materials can broadly be classified as:

- a) Ferrous Metals
- b) Non-ferrous Metals (aluminum, magnesium, copper, nickel, titanium)
- c) Plastics (thermoplastics, thermosets)
- d) Ceramics
- e) Composite Materials
- f) Nano-materials
- g) Smart Materials

Classification of Engineering Materials –



Ferrous Metals:

Ferrous metals are metals that are made up of mostly iron. They are hard, durable, and strong. Most ferrous metals are magnetic, but some types of them are prone to rust and corrosion. Ferrous metals contain other metals, besides iron, and when mixed can yield different properties depending on the metal. These differing properties allow different alloys, or mixtures of metal, to be useful for different applications. For example, the chromium in stainless steel prevents the iron from rusting.

Benefits of Ferrous Metals:

- Most ferrous metals are magnetic
- Wear Resistant
- Low Melting Point
- Cost Effectiveness
- Recyclable

Examples and Uses of Ferrous Metals

Commonly used examples of ferrous metals include steel, stainless steel, carbon steel, cast iron and wrought iron:

1. Steel: A combination of iron and carbon, steel is renowned for its strength and machinability. It is widely used in construction, manufacturing and industrial metal fabrication.

Most carbon steels are *plain carbon steels*, of which there are several types.

- Low-Carbon Steel: Low-carbon steel has less than about 0.30% carbon. It is characterized by low strength but high ductility. Used as wire, structural shapes, machine parts, and sheet metal.
- Medium-Carbon Steel: Medium-carbon steel contains between about 0.30% to 0.70% carbon. It can be heat treated to increase strength, especially with the higher carbon contents. Medium-carbon steel is frequently used for axles, gears, shafts, and machine parts.
- High-Carbon Steel: High-carbon steel contains between about 0.70% to 1.40% carbon. It has high strength but low ductility. Common uses include drills, cutting tools, knives, and springs.

2. Stainless Steel: Stainless steel is an alloy steel made with the addition of chromium around (12%) to steel, which provides resistance against rust.

3. *Tool Steel*: Tool steels are primarily used to make tooling for use in manufacturing, for example cutting tools, drill bits, punches, dies, and chisels. Alloying elements are typically chosen to optimize hardness, wear resistance, and toughness.

4. *Cast Iron*: Cast iron is a ferrous alloy containing high levels of carbon, generally greater than 2%. The carbon present in the cast iron can take the form of graphite or carbide. Cast irons have a low melting temperature which makes them well suited to casting. Cast iron is a hard and wear resistant metal that is widely used for items including cookware, machine tools, engines, manhole covers and water pipes.

- *Gray Cast Iron*: Gray cast iron is the most common type. The carbon is in the form of graphite flakes. Gray cast iron is a brittle material, and its compressive strength is much higher than its tensile strength. The fracture surface of gray cast iron has a gray color, which is how it got its name.
- *Ductile Cast Iron (Nodular Cast Iron)*: The addition of magnesium to gray cast iron improves the ductility of the material. The resulting material is called *nodular cast iron* because the magnesium causes the graphite flakes to form into spherical nodules. It is also called *ductile cast iron*. Nodular cast iron has good strength, ductility, and machinability. Common uses include crankshafts, gears, pump bodies, valves, and machine parts.
- *White Cast Iron*: White cast iron has carbon in the form of carbide, which makes the material hard, brittle, and difficult to machine. White cast iron is primarily used for wear-resisting components as well as for the production of *malleable cast iron*.
- *Malleable Cast Iron*: Malleable cast iron is produced by heat treating white cast iron. The heat treatment improves the ductility of the material while maintaining its high strength.

5. Wrought Iron : It is almost made of pure iron. It contains less carbon than most ferrous metals. This makes it less corrosive but still vulnerable. Wrought iron is used for railings, gates, chains, and agricultural tools.

Non-Ferrous Metals:

Nonferrous metals are lightweight, nonmagnetic, highly conductive, and more resistant to corrosion. Nonferrous metals are more expensive than ferrous metals because they are more complex to produce. These metals are used in a variety of industrial, commercial, and residential applications. Non-ferrous materials are lightweight, softer, and malleable.

Benefits of Nonferrous Metals:

- Easy to Fabricate
- Low Density (less mass)
- High Resistance to Corrosion
- Great Electrical Conductivity
- Recyclable

Types of Nonferrous Metals:

Copper: It is a bright colour that is highly malleable and conductive. Because of its conductivity, it can be used to make electrical wires. Its malleability allows it to be easily shaped without cracking, making it useful for creating statues and manufacturing piping.

Aluminium: It is soft and lightweight, making it easy to work with. It's ideally used for fast manufacturing to produce aircraft components, car parts production, food cans, and much more.

Lead: It is very heavy but soft and malleable. It is used for a lot of protective piping because it is very resistant to corrosion from water and acids, like the piping in power cables or batteries.

Other Metals: Other nonferrous metals include zinc, tin, brass, precious metals like gold, silver, platinum, and much more.

Main Differences between Ferrous and Nonferrous Metals:

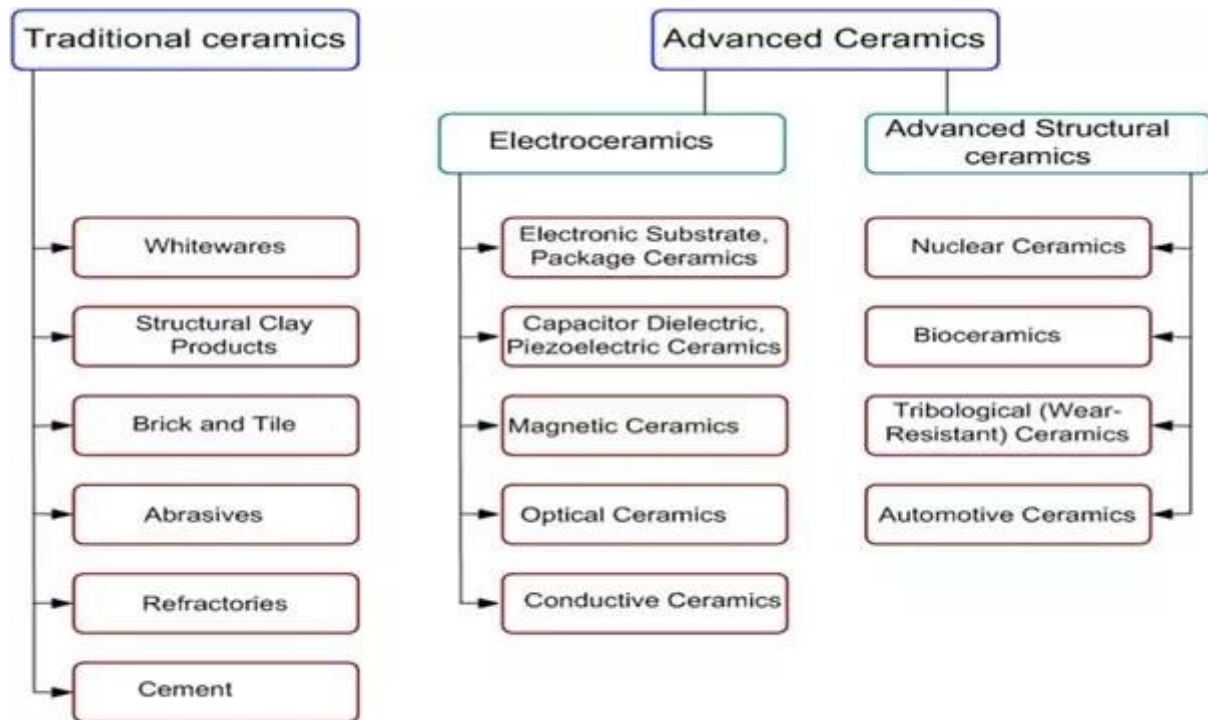
| Ferrous Metal | Nonferrous Metal |
|--|--|
| <ul style="list-style-type: none">• Contain Iron• Magnetic• Durable and Strong• Relatively Inexpensive• More Likely to Rust• Silver | <ul style="list-style-type: none">• Does not Contain Iron• Non-magnetic• Lighter and Malleable• More Expensive• High Corrosion Resistance• Colorful |

CERAMICS:

Ceramics are solid compounds that may consist of metallic or non-metallic elements. The primary classifications of ceramics include glasses, cements, clay products, refractories, and abrasives.

Ceramics generally have excellent corrosion and wear resistance, high melting temperature, high stiffness, and low electrical and thermal conductivity. Ceramics are also very brittle materials

Types of Ceramic Materials:



Glass: Glasses are common materials and are seen in applications including windows, lenses, and containers. Glasses are amorphous, whereas the other ceramics are mainly crystalline. Primary advantages of glasses include transparency and ease of fabrication. The base element of most glasses is silica, and other components can be added to modify its properties. Common processes used to form glass include:

- heating until melting, then pouring into molds to cast into useful shapes
- heating until soft, then rolling
- heating until soft, then blowing into desired shapes

Cements: Cements are materials that, after mixing with water, form a paste that then hardens. Because of this characteristic, cements can be formed into useful shapes while in paste form before they harden into rigid structures. Plaster of paris is one common cement. The most common cement is called Portland cement, which is made by mixing clay and limestone and then firing at high temperature. Portland cement is used to form concrete, which is made by mixing it with sand, gravel, and water. It can also be mixed with sand and water to form mortar. Like other ceramics, cements are weak in tension but strong in compression. Cement is very inexpensive to produce, and it is used widely in the construction of buildings, bridges, and other large structures.

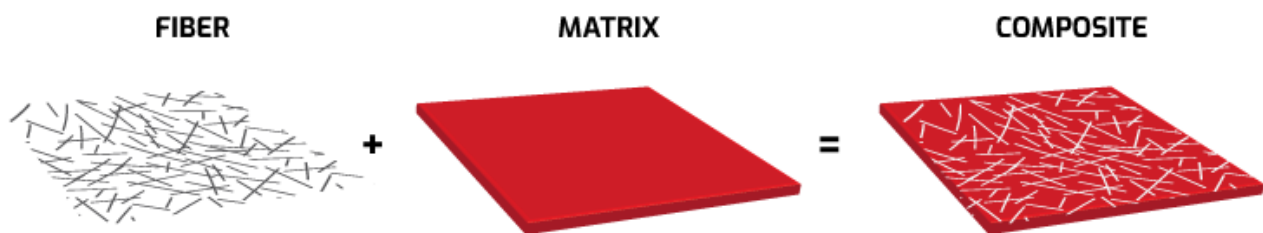
Clay Products: Clay is a very common ceramic material. It can be mixed with water, shaped, and then hardened through firing at high temperature. The two primary classifications of clay products include *structural clay products* and *white wares*. Structural clay products see applications including bricks, tiles, and piping. White wares see applications including pottery and plumbing fixtures.

Refractories: Refractory ceramics can withstand high temperatures and extreme environments. They can also provide thermal insulation. Brick is the most common refractory ceramic.

Abrasives: Abrasive ceramics are hard materials that are used to cut, grind, and wear away other softer materials. Typical properties of abrasives include high hardness, wear resistance, and temperature resistance. Abrasives can either be bonded to a surface (e.g., grinding wheels and sandpaper), or can be used as loose grains (e.g., sand blasting). Common abrasives include cemented carbide, silicon carbide, tungsten carbide, aluminum oxide, and silica sand. Diamond is also an excellent abrasive, but it is expensive.

COMPOSITES:

Composites are simply a combination of two or more constituent materials with different physical or chemical properties. When combined, they produce a material with characteristics different from their original properties. The two main components within a composite are the matrix and fiber. The matrix is the base material while the fiber is what reinforces the material. On top of the fiber reinforcements and matrix, composites can also include core materials, fillers, additives and surface finishes to provide unique performance attributes.

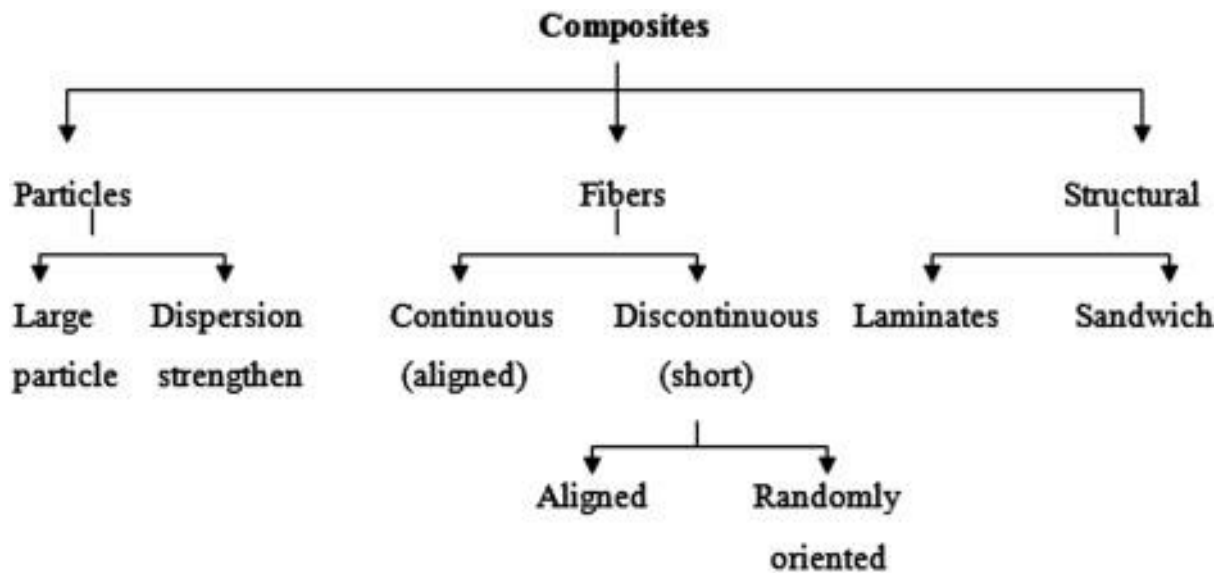


The main composite families encompass

- Organic matrix composites (OMCs),
- Metal matrix composites (MMCs), and
- Ceramic matrix composites (CMCs)

Classification of composites are three main categories:

- Particle-reinforced (large-particle and dispersion-strengthened)
- Fiber-reinforced (continuous (aligned) and short fibers (aligned or random))
- Structural (laminates and sandwich panels)



Types of Composite Material

Currently, composites are widely used in consumer goods and construction materials as a lightweight, economical replacement for metals. Composite materials are being used to create parts that are as massive as passenger aeroplane fuselages. The various types of composite materials are as follows:

- Ceramic matrix composite
- Metal matrix composite
- Reinforced concrete
- Glass fibre reinforced concrete
- Translucent concrete
- Engineered wood
- Plywood
- Engineered bamboo
- Parquetry
- Wood-plastic composite
- Cement-bonded wood fibre
- Fibreglass
- Carbon Fiber reinforced polymer
- Sandwich panel
- Composite honeycomb
- Papier-mache
- Plastic coated paper
- Syntactic foams

Applications of Composite Material:

Composite materials are now used everywhere, in all sectors of application.

- Aerospace
- Automotive & Road Transportation.
- Building & Civil Engineering.
- Defence, Security & Ballistics.
- Design, Furniture and Home.

- Electrical, Electronics, Telecoms & Appliances.
- Equipment & Machinery.
- Marine transportation & Shipbuilding.

Advantages of Composite Material:

Composites have a lot of advantages. Strength, lightness, resistance to corrosion, design flexibility, and durability are essential attributes among them.

Strength: Composites outperform traditional materials like steel in terms of strength per kilogram. Composites' two main ingredients, fibres and resins, both contribute to their tensile strength. The weight is carried by the fibres, and the resins distribute it appropriately throughout the composite part.

Lightweight

Compared to most woods and metals, composite materials are lightweight. In both automobiles and aircraft, lighter weight improves fuel efficiency. Furthermore, lighter materials, from bridge decks to utility poles, are simpler to carry and assemble.

Durable: Composite-built structures are durable and require little care. Boats and other items built of composites have been in use for more than 50 years.

Flexible: Composites have a broad range of material combinations that can be used, which promotes design flexibility. The materials can be specially made to meet the particular requirements of each application. Additionally, composites are simple to mould into complex designs.

Resistant: Unlike other materials, composites are resistant to weather damage and corrosive substances. Because of this, they are suitable for situations where salt water, hazardous chemicals, temperature changes, and other harsh conditions are present constantly.

SMART MATERIALS:

Smart materials have properties that react to changes in their environment. This means that one of their properties can be changed by an external condition, such as temperature, light, pressure, electricity, voltage, pH, or chemical compounds. This change is reversible and can be repeated many times. There is a wide range of different smart materials.

Using a smart material instead of conventional mechanisms to sense and respond, can simplify devices, reducing weight and the chance of failure. Smart materials sense changes in the environment around them and respond in a predictable manner

Types of Smart Materials

There are a number of types of smart material, of which are already common. Some examples are as following:

- Piezoelectric materials are materials that produce a voltage when stress is applied. Since this effect also applies in a reverse manner, a voltage across the sample will produce stress within sample. Suitably designed structures made from these materials can, therefore, be made that bend, expand or contract when a voltage is applied.
- Shape-memory alloys and shape-memory polymers are materials in which large deformation can be induced and recovered through temperature changes or stress changes (pseudoelasticity). The shape memory effect results due to respectively martensitic phase change and induced elasticity at higher temperatures.
- Photovoltaic materials or optoelectronics convert light to electrical current.
- Electroactive polymers (EAPs) change their volume by voltage or electric fields.
- Magnetostrictive materials exhibit a change in shape under the influence of magnetic field and also exhibit a change in their magnetization under the influence of mechanical stress.
- Magnetic shape memory alloys are materials that change their shape in response to a significant change in the magnetic field.
- Smart inorganic polymers showing tunable and responsive properties.
- pH-sensitive polymers are materials that change in volume when the pH of the surrounding medium changes.^[9]
- Temperature-responsive polymers are materials which undergo changes upon temperature.
- Halochromic materials are commonly used materials that change their color as a result of changing acidity. One suggested application is for paints that can change color to indicate corrosion in the metal underneath them.
- Chromogenic systems change color in response to electrical, optical or thermal changes. These include electrochromic materials, which change their colour or opacity on the application of a voltage (e.g., liquid crystal displays), thermochromic materials change in colour depending on their temperature, and photochromic materials, which change colour in response to light—for example, light-sensitive sunglasses that darken when exposed to bright sunlight.
- Ferrofluids are magnetic fluids (affected by magnets and magnetic fields).
- Photomechanical materials change shape under exposure to light.
- Polycaprolactone (polymorph) can be molded by immersion in hot water.
- Self-healing materials have the intrinsic ability to repair damage due to normal usage, thus expanding the material's lifetime.
- Dielectric elastomers (DEs) are smart material systems which produce large strains (up to 500%) under the influence of an external electric field.
- Magnetocaloric materials are compounds that undergo a reversible change in temperature upon exposure to a changing magnetic field.
- Smart self-healing coatings heal without human intervention.
- Thermoelectric materials are used to build devices that convert temperature differences into electricity and vice versa.
- Chemoresponsive materials change size or volume under the influence of external chemical or biological compound.