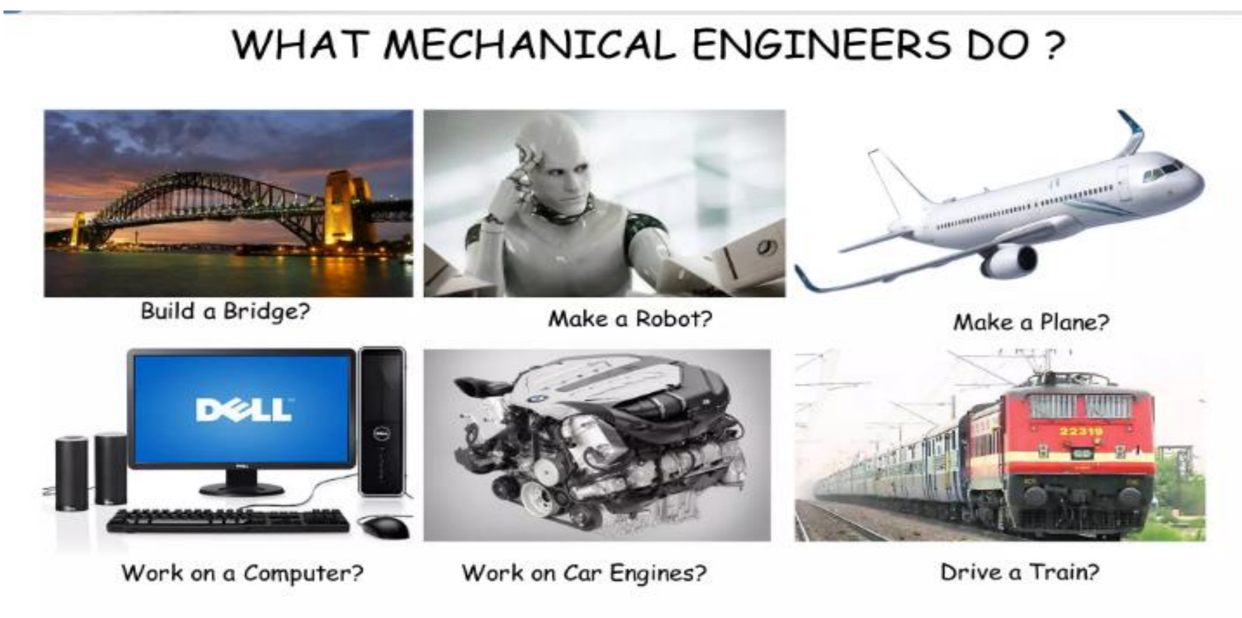
Unit-1 (Basic Mechanical Engineering)

INTRODUCTION TO MECHANICAL ENGG.

ENGINEERING: Engineering is the designing, testing and building of machines, structures and processes using maths and science. Engineering is a discipline dedicated to problem solving.

MECHANICAL ENGINEERING:
Mechanical engineering, the branch of engineering concerned with the design, manufacture, installation, and operation of engines and machines and with manufacturing processes. It is particularly concerned with forces and motion.

What is Mechanical Engineering?
Before entering into the Mechanical Engineer role, let us first understand the concept of Mechanical Engineering. Mechanical Engineering is defined as the branch of engineering that deals with the design, development, construction, and operation of mechanical systems and tools. It include machines, tools, and equipment used in various industries, such as transportation, manufacturing, power generation, and medical devices etc.



ROLE OF MECHANICAL ENGINEERING: Mechanical engineering is one of the broadest engineering disciplines. Mechanical engineers design, develop, build, and test. They deal with anything that moves, from components to machines to the human body.

ROLE OF MECHANICAL ENGINEERING IN INDUSTRY AND SOCIETY: Mechanical Engineers is a blending of principles of physics, mathematics, and materials science to solve problems and improve the efficiency and performance of mechanical systems and devices. They may also work on projects related to energy conservation, sustainability, and renewable energy sources for environmental protection. In this blog, we will explore the role of mechanical engineers in our society in particular and industries in specific.

The Role Of A Mechanical Engineer In Our Society Is Contributed As:

● **Power Generation**: Mechanical engineers design and develop power-generating machines such as internal combustion engines, gas turbines, and steam and wind turbines etc

● **Heating and Cooling Systems**: They design and develop heating, ventilation, refrigeration and air conditioning systems for buildings and other structures.

● **Transportation**: Mechanical engineers are involved in designing and developing transportation systems, including cars, trains, airplanes, steamers and boats.

● ***Industrial Equipment***: They design, develop and maintain industrial equipment such as machine tools, robots, and conveyor systems & belts

● **Infrastructure**: Mechanical engineers play a key role in the design and maintenance of infrastructure, including buildings, bridges, roads, and transportation systems.

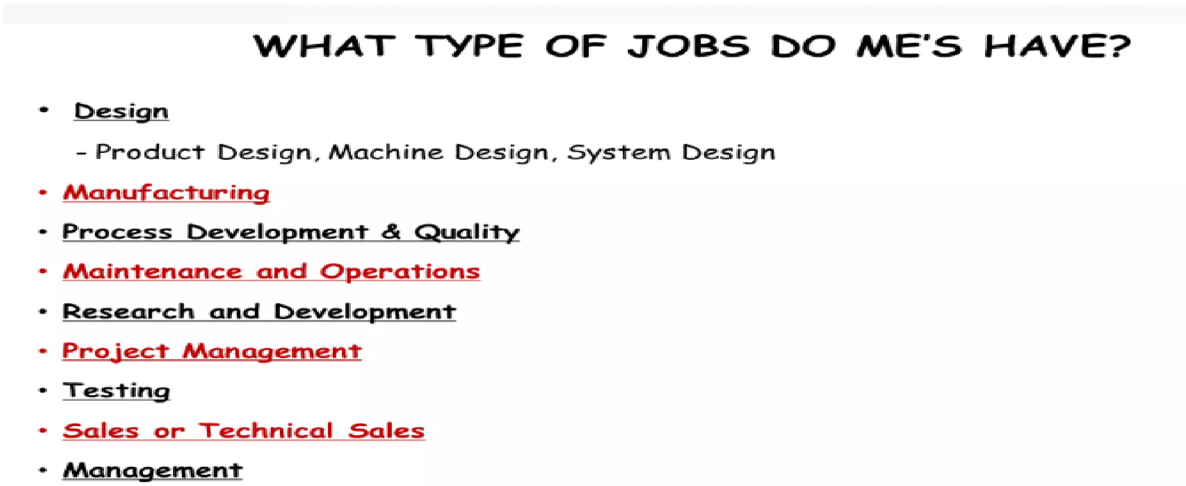
- **HEALTHCARE INDUSTRY** :involved with healthcare industry in creating technologies that are helping doctors and humankind through solving various healthcare problems and creating future solutions. Healthcare devices, individualised medicines as well as surgical devices are been developed by mechanical engineers through the use of 3D-printing technologies.

- **SUPPLY CHAIN.:**Mechanical engineers are not limited to production but also helping scale up the therapeutics, and improve the global supply chain.

- **AUTOMOTIVE INDUSTRY** :With the advent of electric vehicle technology in the automotive industry, mechanical engineers are getting more and more being involved in the design, development manufacturing and testing of hybrid electric vehicles, battery management systems, electrical safety.

- **RENEWABLE ENERGY** :Mechanical engineers have previously been involved in power generation whether hydro or thermal. Recent world has seen their contributions in the development of renewable energy infrastructure across the world starting from huge solar projects, to using wind, ocean or tidal energy to develop power.

- Separately from all of the roles stated mechanical engineers are involved in space exploration, climate change, integration of sensors, controllers and many more. In the Industry 4.0 era, mechanical engineers are working hand in hand with computers to make machines communicate without human involvement keeping the possibility of developing a smart factory.



- SOFT WARE ENGINEERS
- QUALITY ENGINEERING
- HEAVY VEHICLES
- NDT TESTING
- MATERIAL HANDLING
- SAFETY
- MARINE, AERONAUTICAL

CONCLUSIONS: The role of a mechanical engineers is not limited to just manufacturing, but taking a product from its ideation to its customer. To accomplish this, a mechanical engineer must be able to design them for functionality, look into the aesthetics, and work on its durability; and determine the best manufacturing approach that will ensure its operation without failure.Overall, Mechanical Engineers are involved in designing, building, and maintaining the engines, machines, and structures that make modern life possible and comfortable.

TECHNOLOGIES IN MANUFACTURING SECTOR

- TECHNOLOGY: the application of scientific knowledge to the practical aims of human life.
- It includes highly advanced things like computers, to simple things like hammers and wheels. We are surrounded by technology in our lives
- Technology refers to methods, systems, and devices which are the result of scientific knowledge being used for practical purposes.
- Manufacturing is the creation or production of goods with the help of equipment, labor, machines, tools, and chemical or biological processing or formulation.

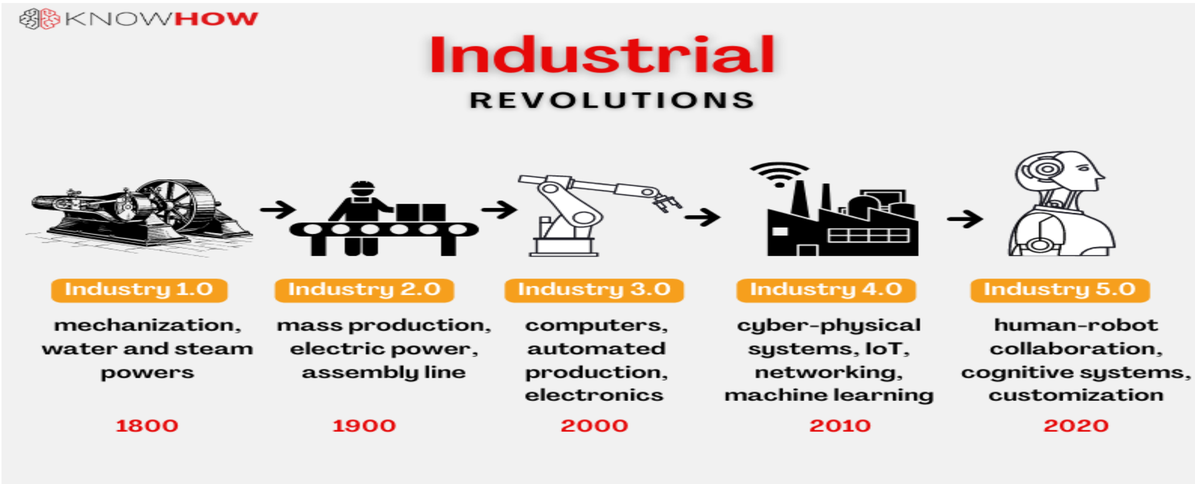
MANUFACTURING PROCESS

Steps of the Manufacturing Process

Develop the Product Vision. The product vision is the seed the finished goods will grow from.

- ➢ Research the Vision

- ➢ Design the Product
- ➢ Finalize the Design
- ➢ Make a Prototype
- ➢ Manufacture the Product
- ➢ Get Feedback and Do More Testing
- ➢ Official Release.



Industry 1.0: **A**round 1760, the First Industrial Revolution was the transition to new manufacturing processes using water and steam. It was hugely beneficial in terms of manufacturing a larger number of various goods and creating a better standard of living for some. The textile industry, in particular, was transformed by industrialization, as was transportation.Fuel sources like steam and coal made machine use more feasible, and the idea of manufacturing with machines quickly spread. Machines allowed faster and easier production, and they made all kinds of new innovations and technologies possible as well.

Industry 2.0: The first Industrial Revolution represented the period between the 1760s and around 1840. This is where the second industrial revolution picked up. Historians sometimes refer to this as "The Technological Revolution" occurring mainly in Britain, Germany and America.During this time, new technological systems were introduced, most notably superior electrical technology which allowed for even greater production and more sophisticated machines.

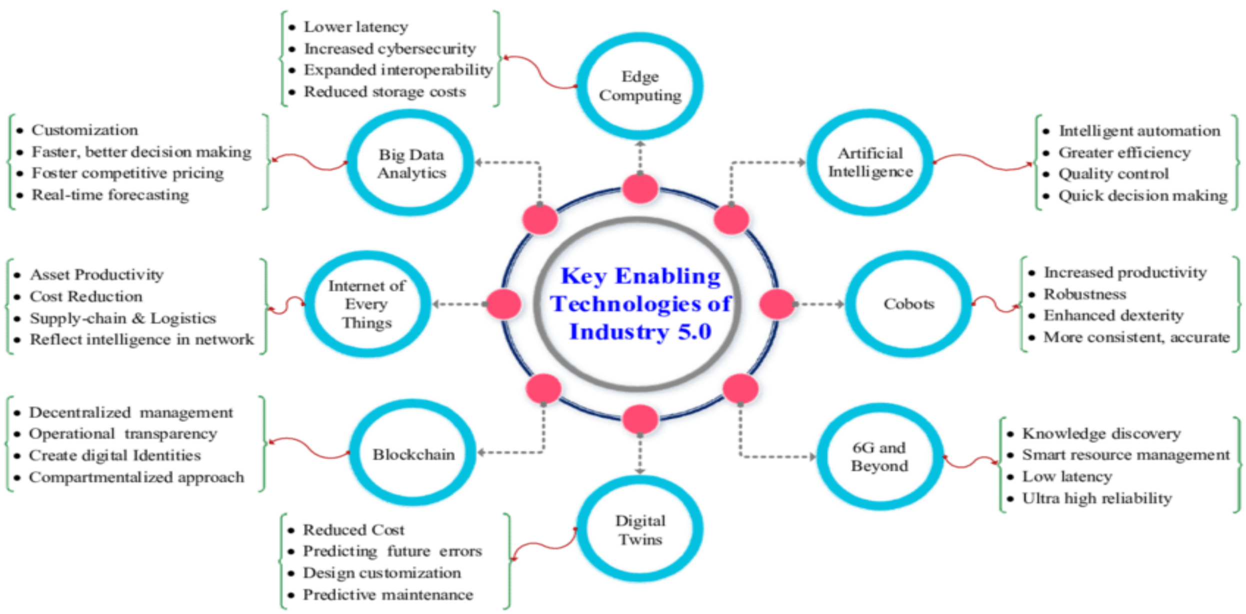
Industry 3.0: It began with the first computer era. These early computers were often very simple, unwieldy and incredibly large relative to the computing power they were able to provide, but they laid the groundwork for a world today that one is hard-pressed to imagine without computer technology.Around 1970 the Third Industrial Revolution involved the use of electronics and IT (Information Technology) to further automation in production. Manufacturing and automation advanced considerably thanks to Internet access, connectivity and renewable energy.Industry 3.0 introduced more automated systems onto the assembly line to perform human tasks, i.e. using Programmable Logic Controllers (PLC). Although automated systems were in place, they still relied on human input and intervention.

Industry 4.0: The Fourth industrial Revolution is the era of smart machines, storage systems and production facilities that can autonomously exchange information, trigger actions and control each other without human intervention. This exchange of information is made possible with the Industrial Internet of things (IIoT) as we know it today. Key elements of Industry 4.0 include:

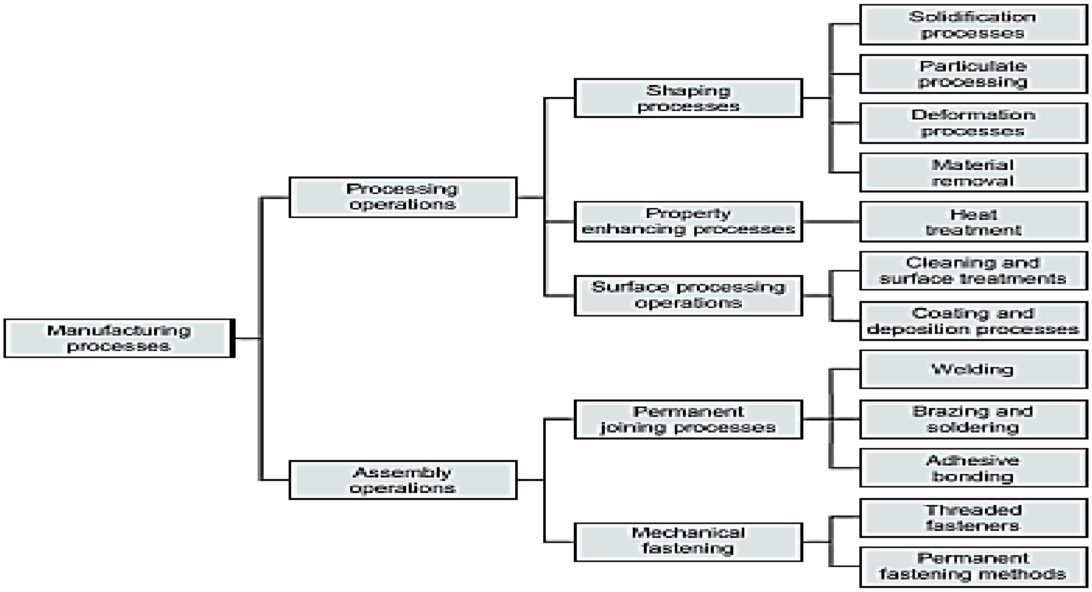
- Cyber-physical system — a mechanical device that is run by computer-based algorithms.
- The Internet of things (IoT) — interconnected networks of machine devices and vehicles embedded with computerized sensing, scanning and monitoring capabilities.
- Cloud computing — offsite network hosting and data backup.
- Cognitive computing — technological platforms that employ artificial intelligence.

"Industry 4.0 starts to move towards Industry 5.0 when you begin to allow customers to customize what they want

Industry 5.0:



Less than a decade has passed since talk of Industry 4.0 first surfaced in manufacturing circles, yet visionaries are already forecasting the next revolution — Industry 5.0. If the current revolution emphasizes the transformation of factories into IoT-enabled smart facilities that utilize cognitive computing and interconnect via cloud servers, Industry 5.0 is set to focus on the return of human hands and minds into the industrial framework. Industry 5.0 is the revolution in which man and machine reconcile and find ways to work together to improve the means and efficiency of production. Funny enough, the fifth revolution could already be underway among the companies that are just now adopting the principles of Industry 4.0. Even when manufacturers start using advanced technologies, they are not instantly firing vast swaths of their workforce and becoming entirely computerized.

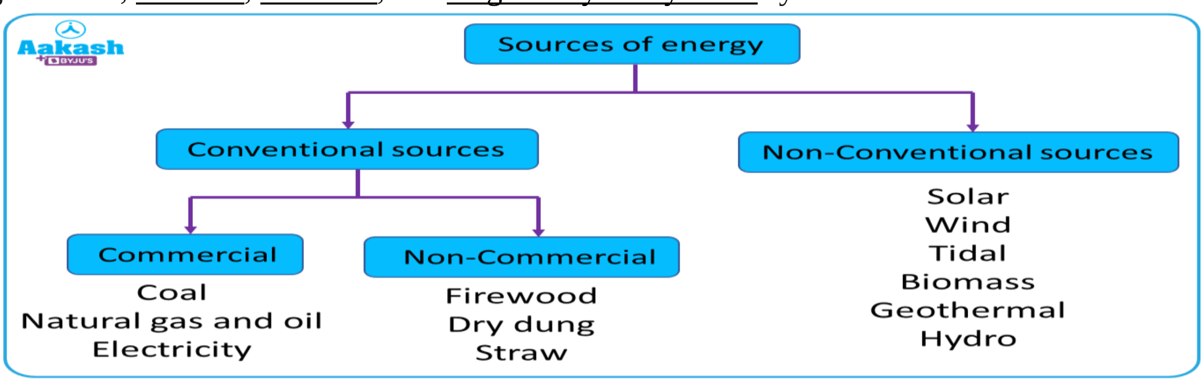


TECHNOLOGIES IN ENERGY SECTOR:

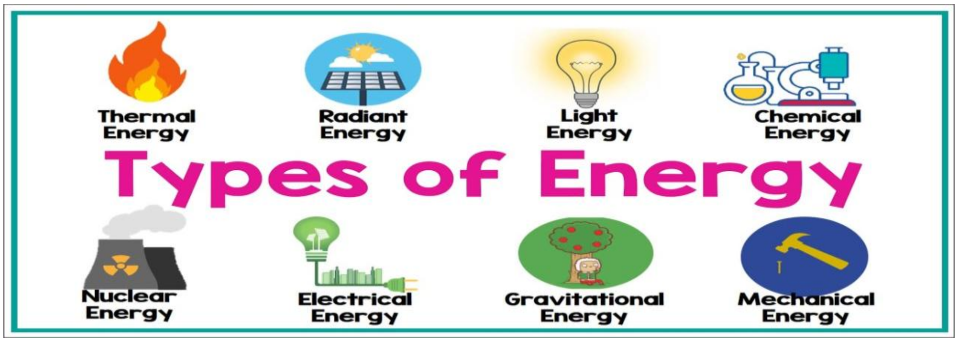
Energy, in physics, the capacity for doing work. It may exist in Potential,Pressure, kinetic, thermal, electrical, chemical, nuclear, or other various forms. There are, moreover, heat and work i.e., energy in the process of transfer from one body to another. Energy can be converted from one form to another in various other ways. Usable mechanical or electrical energy is, for instance, produced by many kinds of devices, including fuel-burning heat engines, generators, batteries, fuel cells,and magneto hydrodynamic systems.

Energy can be neither created nor destroyed but only changed from one form to another. This principle is known as the conservation of energy or the first law of thermodynamics.

Energy can be converted from one form to another in various other ways. Usable mechanical or electrical energy is, for instance, produced by many kinds of devices, including fuel-burning heat engines, generators, batteries, fuel cells, and magneto hydro dynamic systems.



.



Renewable energy uses energy sources that are continually replenished by nature—the sun, the wind, water, the Earth's heat, and plants. Renewable energy technologies turn these fuels into usable forms of energy—most often electricity, but also heat, chemicals, or mechanical power.

Why Use Renewable Energy? Today we primarily use fossil fuels to heat and power our homes and fuel our cars. It's convenient to use coal, oil, and natural gas for meeting our energy needs, but we have a limited supply of these fuels on the Earth. We're using them much more rapidly than they are being created. Eventually, they will run out.

CATEGORIES OF RENEWABLE ENERGY CONVERSION TECHNOLOGIES:

Technology	Energy product	Application
Biomass energy		
Combustion (domestic scale)	Heat (cooking, space heating)	Widely applied; improved technologies available
Combustion (industrial scale)	Process heat, steam, electricity	Widely applied; potential for improvement
Gasification/power production	Electricity, heat (CHP).	Demonstration phase
Gasification/fuel production	Hydrocarbons, methanol, H_2	Development phase
Hydrolysis and fermentation	Ethanol	Commercially applied for sugar/ starch crops; production from wood under development
Pyrolysis/production of liquid fuels	Bio-oils	Pilot phase; some technical barriers
Pyrolysis/production of solid fuels	Charcoal	Widely applied; wide range of efficiencies
Extraction	Biodiesel	Applied; relatively expensive
Digestion	Biogas	Commercially applied
Wind energy		
Water pumping and battery charging	Movement, power	Small wind machines, widely applied
Onshore wind turbines	Electricity	Widely applied commercially
Offshore wind turbines	Electricity	Development and demonstration phase
Solar energy		
Photovoltaic solar energy conversion	Electricity	Widely applied; rather expensive; further development needed
Solar thermal electricity	Heat, steam, electricity	Demonstrated; further development needed
Low-temperature solar energy use	Heat (water and space heating, cooking, drying) and cold	Solar collectors commercially applied; solar cookers widely applied in some regions; solar drying demonstrated and applied
Passive solar energy use	Heat, cold, light, ventilation	Demonstrations and applications; no active parts
Artificial photosynthesis	H_2 or hydrogen rich fuels	Fundamental and applied research
Hydropower	Power, electricity	Commercially applied; small and large scale applications
Geothermal energy	Heat, steam, electricity	Commercially applied
Marine energy		
Tidal energy	Electricity	Applied; relatively expensive
Wave energy	Electricity	Research, development, and demonstration phase
Current energy	Electricity	Research and development phase
Ocean thermal energy conversion	Heat, electricity	Research, development, and demonstration phase
Salinity gradient / osmotic energy	Electricity	Theoretical option
Marine biomass production	Fuels	Research and development phase

TECHNOLOGIES IN AUTOMOTIVE:

- Automotive innovation is utilizing new technologies and ideas to advance automobiles' design, performance, and efficiency.
- Over the past few decades, the automotive industry has witnessed a remarkable transformation, with the recent technology trends disrupting how the value is delivered to the customers.
- The automotive industry is rapidly changing, with innovations and technology set to revolutionize how we get around. From electric cars to driverless vehicles, coming future promises exciting advances in the automotive sector.

I. Artificial Intelligence
II. Big Data & Analytics
III. Human-Machine Interfaces (HMI)
IV. Internet of Things.
V. Autonomous Vehicles
VI. ADAS (Advanced Driver Assistance System)
VII. Electrification.

Artificial Intelligence:

The automotive industry has seen a surge in artificial intelligence (AI) technologies, such as machine learning, deep learning, and computer vision.

- These are used to guide self-driving cars, manage fleets and assist drivers for improved safety. AI also plays a role in improving services such as vehicle inspections or insurance. In addition, AI accelerates production rates and lowers costs through robotic automation in manufacturing.

Big Data & Analytics:

Vehicle lifecycles are greatly influenced by the data gathered from connected vehicles. Predictive maintenance is enabled by this data, allowing fleet managers to monitor performance and alert authorities in case of accidents.

- Automotive customer data also drives sales, optimizing supply chains and improving product design for newer vehicles.

Human-Machine Interfaces (HMI):

Self-driving and connected vehicles are revolutionizing the automotive industry. Human Machine interface systems like Voice-based systems allow drivers to interact with their vehicles, making the driving experience safer and more enjoyable. Smart virtual assistants to help drivers and passengers interact with their vehicles and service providers.

Internet of Things (IoT) technology allows vehicles to be connected to the internet and exchange data with other devices, enabling a range of features such as remote vehicle monitoring, predictive maintenance, and real-time traffic updates. This trend is being driven by the increasing demand for connected and convenient vehicles, as well as the growing awareness among car manufacturers of the benefits of IoT technology in terms of improving vehicle performance and enhancing the overall driving experience.

Autonomous Vehicles: Self-driving or autonomous vehicles lessen the need for human drivers and provides more excellent safety, convenience, and efficiency. AI-enhanced computer vision and other advanced technologies are used in AVs to detect obstacles along their route, reducing the potential for accidents due to driver error or fatigue. Autonomous Vehicles are advancing rapidly and offer tremendous promise for a more connected and efficient future.

ADAS (Advanced Driver Assistance System)ADAS technology includes features such as lane departure warning, automatic emergency braking, and adaptive cruise control, which can enhance the safety and convenience of driving, provided the infrastructure is in place to use these features. This trend is being driven by several factors, including the increasing demand for safer vehicles among consumers, the government's push for increased road safety, and the availability of more affordable ADAS technology.

Electrification:

- Fossil fuel reserves are depleting, and their use is detrimental to the environment. To address this, electric mobility solutions must be promoted to reduce overall greenhouse gas emissions worldwide. However, high prices, poor battery life, inadequate charging infrastructure, and fleet electrification prevent greater adoption of electric vehicles (EVs).

3D Printing (Additive manufacturing):

- 3D printing enables rapid prototyping and shortens the design and testing phases of production.

- Manufacturers can print spare parts quickly and easily to their exact specifications while additive manufacturing of composite materials leads to automotive parts that are lightweight, durable, and stronger than ever before. This enables lighter, more efficient cars with enhanced performance.

Blockchain:

- Blockchain technology is revolutionizing the automotive industry, from providing secure and reliable data sharing and connectivity networks to supporting shared mobility solutions such as ride-hailing and urban transportation.
- It also verifies the supply chain of spare parts, ensuring that only legitimate and trusted sources are utilized for raw materials and spares. By embracing blockchain, the automotive industry opens opportunities for more secure, efficient, and accurate services.

TECHNOLOGIES IN AEROSPACE SECTOR

The aerospace engineering industry deals with aircraft, spacecraft, and related tools & technologies. Mechanical engineers study, design, and produce aerospace solutions.

There is a high demand for quality BTech in mechanical engineering. The industry is becoming more innovative-driven, and they require experts in the trade.

Job Responsibilities of Mechanical Engineers in the Aerospace Sector

Aerospace engineers research, develop, test, launch, and monitor various tools and solutions.

Application of aero-modelling, dynamics, and other principles of physics for design, changes in design and productivity for the end purpose.

TECHNOLOGIES IN MARINE SECTOR

- The maritime industry is the backbone of global trade and commerce, carrying over 90% of goods of all types across the world.
- With the onset of the Covid-19 pandemic, there has been a significant surge in e-commerce, leading to a higher demand for efficient and cost-effective sea transportation services.
- Furthermore, the maritime sector is increasingly focusing on reducing its environmental impact. To achieve this, digital technologies are unavoidable.
- During this year 2023, they will drive some exciting innovations in the maritime industry, to enhance the sector’s sustainability and efficiency and to cater to ever-growing customers’ requirements.
- The maritime industry has witnessed significant technological innovations, leading to a ripple effect across the entire supply chain.
- Digital platforms for ship and cargo tracking, as well as the implementation of digital communication and collaboration tools, have become commonplace in the industry.
- But other innovative solutions stand out, presenting exciting opportunities in various areas. These aim to make the shipping faster, safer, more efficient, and greener.

Robotics technology

- has the potential to alleviate humans from monotonous, hazardous, physically demanding, or heavy work.
- In port terminals, automated cargo handling systems are contributing to fast and efficient operations, lower risk of human errors, reduced emissions, and minimized waiting times at anchor or at the quay for ships.

- For example, autonomous cranes are deployed in all major ports in the United States, Canada, Asia (China, Singapore, India…), Europe (UK, Germany, France, Spain, the Netherlands…), Australia, etc.
- The development of robotics technology also aims to address labor shortages and improve overall productivity compared to manual operations.

Big data and analytics

The entire supply chains generate large amounts of data that are collected and analyzed to review and improve usages and processes, by creating patterns, identifying trends, and take well-founded decisions.

For instance, **data-driven insights** can be controlled for the following tasks:forecast demand;

optimize sailing routes by shipping companies in order to reduce fuel consumption and carbon footprint (minimize emissions and waste, improve recycling…);

lower costs and risks of accidents;

identify innovative ways to gain efficiency and generate additional revenue;

Internet of Things (IoT)

Connected sensors placed on trucks, vessels, advanced navigation systems, or other equipment transmit various data such as location, speed, and functions, through dedicated software, continuously or at a predefined frequency.

Combined with GPS and satellite observation, this information is used to track shipments, to plan operations at the next port of call.

IoT also plays a key role in predictive maintenance by utilizing historical and real-time data along with a system of alerts to immediately inform concerned teams when an abnormality occurs. This reduces response time and avoids time-consuming repairs.

The advanced monitoring systems used in the maritime industry are designed to constantly monitor the state of the environment in real-time (air and water quality, weather patterns, and vessel traffic).

These systems use a combination of sensors, satellite imagery, and other technologies to collect and analyze data about the ocean and surrounding environment.

The data collected by these systems is then used to create detailed maps and models of the ocean and to alert ship operators and authorities about potential environmental hazards or emergencies. This information can help prevent pollution and protect marine ecosystems[open deep sea,coral reefs,mangroves,sandy beach,polar marine,rocky marine], while also reducing the costs associated with clean-up efforts in the event of an environmental disaster.

Artificial and Augmented Intelligence

Artificial intelligence has become an indispensable tool for developing in the era of digital services. At Sinay, our AI-based modules help maritime industry professionals calculate ETA [estimated time of arrival] for any vessel worldwide, monitor air/water quality, assess underwater noise, etc.

Artificial intelligence is also vital to move towards smart ports, combined with 5G connection, **Big Data, Internet of Things (IoT), and blockchain technology.**

The ports of Los Angeles, Rotterdam, Quebec, Le Havre, Hamburg, Shanghai, and Singapore, among others, show how technology is making digital transformation a reality, bringing efficiency, transparency, and sustainability.

Cloud and SaaS[software as a service]

Working mobile has become the norm, especially since the pandemic. All business applications and information have to be accessible anytime and anywhere on any connected device, using a cloud-based computing system. This increases flexibility, effectiveness, and responsiveness.

- Moreover, data sharing is key to ensuring smooth communication, operations, or vessel/truck fleet management between remote sites, or even between sailing vessels and shore-based teams. Being on the same level of information allows quick and relevant decision-making.
- **Autonomous ships**
- IT will revolutionize the ocean transportation industry. Using an array of technologies including sensors, cameras, and advanced algorithms, these vessels can operate and navigate without human intervention.
- Beyond cost savings, autonomous technologies offer:
- improved safety due to their ability to detect and avoid collisions,
- reduced fuel consumption,
- optimized scheduling and routing that leads to shorter and more reliable delivery times.

Green shipping

- As the demand for sustainability in the maritime industry grows, there is an increasing focus on alternative fuels such as liquefied natural gas (LNG), biofuels, hydrogen, and ammonia to reduce the sector's reliance on fossil fuels and the carbon footprint of vessels.
- Additionally, **technological solutions** that improve energy efficiency, both in machinery (such as propulsion systems) and onboard vessels (including lighting and other appliances), are being explored.
- Moreover, since January 2023, the shipping industry undergoes a significant regulatory change with the introduction of the Energy Efficiency Existing Ship Index (EEXI) measurement,
- which will be mandatory for each ship, as part of the yearly assessment of their carbon intensity indicator (CII). Both aim at promoting more sustainable and energy-efficient practices.
- Similarly, advancements in ship design, the use of ecological materials, and the development of hull coatings can all help to reduce fuel consumption and pollutant emissions, contributing to a greener future for the maritime industry and a healthier planet for us all.

Engineering Materials

- Engineering materials are used to provide the mechanical strength and stiffness. There are different classes of engineering materials which include composites, ceramics, polymers, and metals.
- They are designed to ensure a combination of the best properties of each of the component materials. There is also an increasing trend to classify engineering materials into two further categories: structural materials and functional materials.
- Material is a substance or mixture of substances that constitutes an object. Materials can be pure or impure, living or non-living matter. Materials can be classified on the basis of their physical and chemical properties, or on their geological origin or biological function.

CLASSIFICATION OF MATERAILS

Metallic materials are divided into two types

1. Ferrous materials
2. Non-ferrous materials

The ferrous materials are iron based and the non ferrous materials are having some elements other than iron as the principal constituent

The bulk of the non ferrous materials are made up of the alloys of copper, aluminum, magnesium, nickel, tin, led& zinc. Other non-ferrous materials and alloys are used to a lesser extent include cadmium, molybdenum, cobalt, zirconium, beryllium, titanium and the precious metals gold, silver and the platinum.

- Common engineering materials are normally classified as metals and nonmetals.
- **Metals** may conveniently be divided into ferrous and non- ferrous metals. Important ferrous metals for the present purpose are: i. cast iron, ii. wrought iron, iii. steel.

Some of the important non-ferrous metals used in engineering design are:

(a) Light metal group such as aluminum and its alloys, magnesium and manganese alloys.
(b) Copper based alloys . (c)White metal group such as nickel, silver, bearing metals.

FERROUS METALS: **Cast Iron-**

It is an alloy of iron, carbon and silicon and it is hard and brittle. Carbon content may be within 1.7% to 3% and carbon may be present as free carbon (graphite) or iron carbide Fe_3C.

In general the types of Cast Iron are: a. Grey Cast Iron b. White Cast Iron C.Malleable Cast Iron d. Spheroidal or nodular cast iron e. Austenitic cast iron f. Abrasion resistant cast iron.

Grey cast iron Carbon content is 3 to 3.5%. Carbon here is mainly in the form of graphite. This type of cast iron is inexpensive and has high compressive strength. It has low tensile strength and low ductility. Graphite is an excellent solid lubricant and this makes it easily machinable but brittle. Some examples of this type of cast iron are FG20, FG35 or FG35Si15. The numbers indicate ultimate tensile strength in MPa and 15 indicates 0.15% silicon.

Applications:

Due to lubricating action it is very suitable for parts where sliding action is desired. They are machine tool bodies, automotive cylinder blocks, heads, housings, fly-wheels, pipes and pipe fittings and agricultural implements.

Austenitic cast iron: Depending on the form of graphite present this cast iron can be classified broadly under two headings: Austenitic flake graphite iron, Austenitic spheroidal or nodular graphite iron .These are alloy cast irons and they contain small percentages of silicon, manganese, sulphur, phosphorus etc. They may be produced by adding alloying elements viz. nickel, chromium, molybdenum, copper and manganese in sufficient quantities. These elements give more strength and improved properties. They are used for making automobile parts such as cylinders, pistons, piston rings, brake drums etc.

White cast iron- Carbon content is 1.75 to 2.3%.In these cast irons carbon is present in the form of iron carbide (Fe_3C). which is hard and brittle. White cast iron has high tensile strength and low compressive strength. The presence of iron carbide increases hardness and makes it difficult to machine. Consequently these cast irons are abrasion resistant.

Applications: Due to wear resisting characteristics it is used for car wheels, rolls for crushing grains and jaw crusher plates

Abrasion resistant cast iron: These are alloy cast iron and the alloying elements render abrasion esistance. A typical designation is ABR33 Ni4 Cr2 which indicates a tensile strength in kg/mm^2 with 4% nickel and 2% chromium.

Malleable cast iron- These are white cast irons rendered malleable by annealing. These are tougher than grey cast iron and they can be twisted or bent without fracture. They have excellent machining properties and are inexpensive. Depending on the method of processing they may be designated as black heart BM32, BM30 or white heart WM42, WM35 etc.

Applications:

Malleable cast iron is used for making parts where forging is expensive such as hubs for wagon wheels, brake supports.

Spheroidal or Nodular graphite cast iron: In these cast irons graphite is present in the form of spheres or nodules. This type of cast iron is formed by adding small amounts of magnesium (0.1 to

0.8%) to the molten grey iron. The addition of magnesium causes the graphite to take form of nodules or spheroids instead of normal angular flakes. They have high tensile strength and good elongation properties. They are designated as, for example, SG50/7, SG80/2 etc where the first number gives the tensile strength in MPa and the second number indicates percentage elongation.
Applications:Nodular cast iron is generally used for casting requires shock and impact resistance along with good machinability, such as hydraulic cylinders, cylinder heads rolls

Wrought iron:

- This is a very pure iron where the iron content is of the order of 99.5%. It is produced by re-melting pig iron and some small amount of silicon, sulphur, or phosphorus may be present. It is tough, malleable and ductile and can easily be forged or welded. It cannot however take sudden shock.
- Applications- Chains, crane hooks, railway couplings and such other components may be made of this iron.

Steel:

This is by far the most important engineering material and there is an enormous variety of steel to meet the wide variety of engineering requirements. Steel is basically an alloy of iron and carbon in which the **carbon** content can be less than **1.7%** and carbon is present in the form of iron carbide to impart hardness and strength.

Two main categories of steel are

(a) Plain carbon steel:

The properties of plain carbon steel depend mainly on the carbon percentages and other alloying elements are not usually present in more than 0.5 to 1% such as 0.5% Si or 1% Mn etc. There is a large variety of plane carbon steel and they are designated as C01, C14, C45 and C70 and so on where the number indicates the carbon percentage.

Following categorization of these steels is sometimes made for convenience:

- ✓ Dead mild steel- up to 0.15% C
- ✓ Low carbon steel or mild steel- 0.15 to 0.46% C
- ✓ Medium carbon steel- 0.45 to 0.8% C.
- ✓ High carbon steel- 0.8 to 1.5% C

LOW CARBON STEEL-(MILD STEELS (OR) SOFT STEELS)- No alloying element other than carbon content of 0.15% to 0.45%. Its hardness cannot be increased by conventional heat treatment method. The hardness number is about 150BHN. It has lower tensile strength and malleable.

Applications- Screws, bolts, nuts, washers, wire fences, automobile body sheet, plates, wires, building bars, grills, beams, angles, channels etc.

MEDIUM CARBON STEEL-(MACHINERY STEELS): The carbon content of is 0.45% to 0.8% has higher tensile strength and hardness than low carbon steels. The hardness number is about 300BHN.

Applications- Hooks, wire ropes, shafts, connecting rods, spindles, rail axles, gears, turbine bucket wheels, steering arms and other machine components which require medium strength.

HIGH CARBON STEEL: carbon content of 0.8% to 1.7%.High carbon steels good wear resistance good wear resistance

(a) Alloy steel: These are steels in which elements other than carbon are added in sufficient quantities to impart desired properties, such as wear resistance, corrosion resistance, electric or magnetic properties.

Chief alloying elements added are usually

- Nickel for strength and toughness
- Chromium for hardness and strength
- tungsten for hardness at elevated temperature
- vanadium for tensile strength
- manganese for high strength in hot rolled and heat treated condition
- silicon for high elastic limit
- cobalt for hardness
- molybdenum for extra tensile strength

Stainless steel

is one such alloy steel that gives good corrosion resistance. One important type of stainless steel is often described as **18/8 steel where chromium and nickel percentages are 18 and 8 respectively**. A typical designation of a stainless steel is 15Si2Mn2Cr18Ni8 where carbon percentage is 0.15.

High speed steel:

This steel contains 18% tungsten, 4% chromium and 1% vanadium. It is considered as one of best of all purpose tool steels. It is used widely for drills, lathe, planer and shaper tools, milling cutters, reamers, broaches, threading dies, punches etc.

Non-ferrous metals- Metals containing elements other than iron as their chief constituents are usually referred to as non-ferrous metals. There is a wide variety of non-metals in practice.

Ex: Aluminium, Copper, Lead, Tin, Nickel, Zinc etc... Its properties over ferrous metals:

1. Resistance to corrosion 2. Special electrical and magnetic properties.

3. Soft and facility of cold working. 4. Attractive colour. 5. Low density. Good formability.

Aluminum- This is the white metal produced from Alumina. In its pure state it is weak and soft but addition of small amounts of Cu, Mn, Si and Magnesium makes it hard and strong. It is also corrosion resistant, low weight and non-toxic

Duralumin- This is an alloy of 4% Cu, 0.5% Mn, 0.5% Mg and aluminum. It is widely used in automobile and aircraft components.

Y-alloy- This is an alloy of 4% Cu, 1.5% Mn, 2% Ni, 6% Si, Mg, Fe and the rest is Al. It gives large strength at high temperature. It is used for aircraft engine parts such as cylinder heads, piston etc.

Magnalium- This is an aluminum alloy with 2 to 10 % magnesium. It also contains 1.75% Cu. Due to its light weight and good strength it is used for aircraft and automobile components.

Copper alloys

Copper- is one of the most widely used non-ferrous metals in industry. It is soft, malleable and ductile and is a good conductor of heat and electricity.

Brass (Cu-Zn alloy) - It is fundamentally a binary alloy with Zn up to 50% . As Zn percentage increases, ductility increases up to ~37% of Zn beyond which the ductility falls. Small amount of other elements viz. lead or tin imparts other properties to brass. Lead gives good machining quality ductility Zn (%) 37 and tin imparts strength. Brass is highly corrosion resistant, easily machinable and therefore a good bearing material

Bronze (Cu-Sn alloy)-This is mainly a copper-tin alloy where tin percentage may vary between 5 to 25. It provides hardness but tin content also oxidizes resulting in brittleness. Deoxidizers such as Zn may be added.

Gun metal- is one such alloy where 2% Zn is added as deoxidizing agent and typical compositions are 88% Cu, 10% Sn, 2% Zn. This is suitable for working in cold state. It was originally made for casting guns but used now for boiler fittings, bushes, glands and other such uses.

IMPORTANT PROPERTIES OF COPPER:-

1. High electrical and thermal conductivity.
2. Good corrosion resistant, mechinability, strength and ease of fabrication.
3. It is having pleasing color and can be welded, brazed, soldered and easily finished by platingor lacquering.

APPLICATIONS:-

1. electrical conductors ,roofing, gutters, down-spouts, automobile radiators and gaskets, vatspressure vessels, distillery and process equipment.
2. electronics tubes.,condenser and heat exchanger applications.
3. switch gears, relays and precession electrical equipment.

Lead alloys: The tin is replaced by lead base alloys and contains 10 – 15% antimony, 15% Cu, 20% Tin and 60% Lead. These alloys are cheaper than tin base alloys, but not strong and do not possess the lead carrying capacity strength decreases with increasing in temperature. An alloy containing 80% lead, 15% antimony and 5% tin or 20% antimony generally used for long bearings with medium loads.

Zinc alloys:

These alloys used in the form of tooling plate and easy and speed of fabrication. Brasses – Alloys of Cu and Zn.

*Nickel alloys:*Nickel is one of the most important metals which is used as a pure metal and alloyed with other elements.

Nickel copper, nickel copper silicon alloys.
Nickel copper tin, sometimes with lead.
Nickel chromium- with iron or cobalt.
Nickel molybdenum-also with chromium.
Nickel silicon.

Ceramics: Ceramics are made of clay, earthen elements, powders, and water. These components are combined, molded into the desired shape, and then fired or otherwise heated to finish the fabrication.

The specific types and proportions of materials involved can vary depending on the desired characteristics of the ceramic product. For example, some ceramics may be made from pure clay while others may be blended with additives such as feldspar or silica to enhance their properties. Advanced ceramics intended for specialized applications may be made from more exotic materials such as tungsten carbide, or zirconia

Ceramics are also used to make objects as diverse as spark plugs, fiber optics, artificial joints, space shuttle tiles, cooktops, race car brakes, micropositioners, chemical sensors, self lubricating bearings, body armor, and skis.

material’s characteristics. Ceramic materials tend to be:

1. Harder and more brittle than metals ,2. Wear-resistant , 3. Refractory, 4. Good thermal and electrical insulators, 5. Nonmagnetic, 6. Oxidation-resistant ,7. Chemically stable

The mechanical properties of ceramics include:

1. Poor impact strength, 2. High compressive strength, 3. Extremely stiff and rigid structure with little or no yielding, 4. The presence of microcracks can cause local stress concentrations and brittle fracture, 5. Hardness and strength in compression, with a high softening temperature, 6. Poor thermal shock resistance, 7. Brittle natureics

Different Advanced Applications:

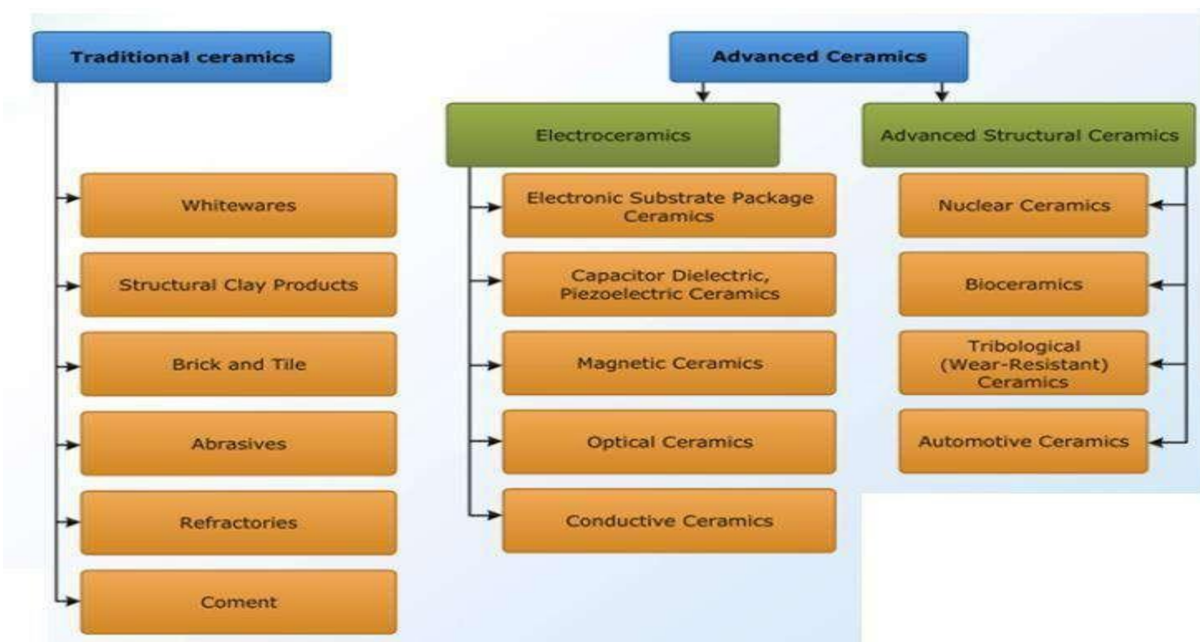
1. **Aerospace:** Ceramics make up some high-temperature components such as turbine blades, heat shields, and nose cones. Although these materials are hard to shape using conventional manufacturing methods, 3D printing is now being used to build aerospace parts out of ceramics.
2. **Biomedical:** Ceramics show up in medical implants due to their biocompatibility, strength, and wear resistance.
3. **Electronics:** Electronic devices receive ceramic components because of the material's electrical insulation properties and ability to dissipate heat.
4. **Energy:** Ceramic materials are important to energy applications such as fuel cells, solar panels, and thermal insulation due to their thermal stability and temperature resistance.

IMPORTANT PROPERTIES:

1. ceramic`s are in-organic, non-metallic materials that are pass and /or used at high temperatures
2. They have been subjected to heat treatment
3. They are generally hard & brittle materials that with stand compression very well
4. They are abrasive resistance, heat resistance &can curtain large compressive loads even athigh temperature
5. many ceramic`s are chemically inert even at high temperatures as shown by good oxidationand reduction resistance at these temperature
6. The nature of chemical bond in ceramics generally ionic in character and the coins play onimportant role in the determination of the properties of the material

EX: anions, carbides, borides, nitrides, oxides.

TYPES OF CERAMIC`S: 1. Classification of ceramics based on function



EXAMPLES OF CERAMIC MATERIALS:

1. All types of glass product including fibers etc.
2. Cements, line, plaster
3. Abrasives & some types of cutting of tools
4. Bricks, tiles, drain, pipes etc.
5. Refractories for high temperature use
6. Electrical insulators, Ferro magnetic, semi conductors

ADVANTAGES OF CERAMIC MATERIALS:

1. The ceramics are hard, strong & dense.
2. They have high resistance to the action of chemically and to the weathering
3. Passes a high compression strength compressed with tension
4. They offer excellent di-electric properties
5. They are good thermal insulators
6. Good sanitation
7. Better economy

APPLICATIONS:

1. **WHITE WARES:** tools, sanitary wares, high frequency applications, chemical industries etc
2. **NEWER CERAMICS:** borides, carbides, nitrides, single oxides, mixed oxides, silicates,insulators, semi conductors, fuel elements, fuel containers, control rods etc.
3. **ADVANCED CERAMICS:** these are in I.C engines, turbines, cutting tools, energy conversation, strong & generation

GLASSES:

1. Glass is a transparent silica product which may be amorphous (or) crystalline. Dependingupon the heat treatment
2. Glass is in-organic product of faction in one (or) more oxides of silicon, boron, calcium, mg,Na etc … cooled to rigid material without crystallization
3. Glasses mostly consist of in-organic oxides such as SiO2 & B2O 3 are known as glass formers

Many other oxides such as Al2O3, CaO, Na2o MgO etc…are added to glass forming oxides to obtain derived combination of properties such as refractories index, electrical conductivity etc…

GLASS PRODUCTION & PROCESSING STEPS:

1. Melting & refining ~ melting point = 1500 c
2. Forming & shaping
3. Heat treatment
4. Finishing

PROPERTIES OF GLASS:-

1. Viscosity: - which determines the suitability of glass for drawing into tubes, rods, for blowing& rolling
2. Chemical stability:- Which determines the suitability of glass for making chemical wears & optical glasses.
3. Optical properties:-this determine the stability of glass for use in optical system
4. Mechanical properties:-tensile strength & wear resistance.
5. Electrical properties: - good conductivity di-electric and determine the stability of glass for

manufacturing the incandescent lamps, radio, valves, x-ray tubes etc

APPLICATIONS OF GLASS:-

1 In doors, windows, furnitures etc..

2. Laboratory equipment & chemical glass wear

3. X-ray tubes, glass tubes, fiber glass insulation, optical glasses

Automobile Engine parts Advantages: Operate at high temperatures – high efficiencies; Low frictional losses; Operate without a cooling system; Lower weights than current engines Disadvantages: Ceramic materials are brittle; Difficult to remove internal voids (that weaken structures);

Ceramic parts are difficult to form and machine Potential materials: Si 3 N4 (engine valves, ball bearings), SiC (MESFETS), & ZrO2 (sensors), Possible engine parts: engine block & piston coatings

Applications of Ceramics

Ceramics have a wide range of applications across various industries due to their unique properties and versatility. Here are five common applications of ceramics:

1. Electronics and Electrical Engineering:

2. Aerospace and Defense:

3. Biomedical and Dental:

4. Automotive Industry:

5. Architecture and Construction:

Advantages of Ceramics

Ceramics offer a multitude of advantages that make them highly desirable materials, including exceptional strength, heat resistance, chemical resistance, electrical insulation, and aesthetic appeal, among others.

 High Strength: Ceramics exhibit exceptional strength, making them ideal for applications that require durability and resistance to wear and tear.

 Hardness: Ceramics are known for their hardness, which enables them to withstand harsh conditions and resist scratching and abrasion.

 Heat Resistance: Ceramics have excellent thermal stability and can withstand high temperatures without deforming or losing their structural integrity. This property makes them suitable for use in high-temperature environments such as furnaces and engines.

 Chemical Resistance: Ceramics are highly resistant to chemical corrosion, allowing them to be used in industries where exposure to harsh chemicals is common, such as the chemical processing and pharmaceutical industries.

 Electrical Insulation: Ceramics are excellent electrical insulators, meaning they do not conduct electricity. This property makes them ideal for
applications in electrical and electronic components where insulation is crucial.

 Low Thermal Expansion: Ceramics have low coefficients of thermal expansion, meaning they expand and contract minimally with temperature changes. This property makes them resistant to thermal shock and allows for precise dimensional stability.

Disadvantages of Ceramics: they have some drawbacks, such as brittleness, difficulty in shaping complex designs, and a tendency to crack under sudden changes in temperature or stress.

 Brittleness:

 Limited ductility:

 High processing costs:

 Poor thermal shock resistance:

 Difficulty in machining:

Composite materials A material consisting of two or more physically and chemically distinct parts, suitably arranged, having different properties respect to those of the each constituent parts. (matrix and reinforcement), in order to to obtain the mechanical characteristics (and sometimes thermal) higher than that it is possible to have with their corresponding matrices is called Composite.It can be natural or artificially made materials.

The desired properties are:

Strength, Stiffness, Toughness, High corrosion resistance, High wear resistance, High chemical resistance, High environmental degradation resistance, Reduced weight, High fatigue life, Thermal insulation or conductivity, Electrical insulation or conductivity, Acoustic insulation, Radar transparency, Energy dissipation, Reduced cost, Attractiveness etc...

The constituents in a typical composite: In a composite, typically, there are two constituents. One of the constituent acts as a Matrix and other acts or called as a Reinforcement. Sometimes, the constituents are also referred as *phases*.

Classifications of composites:

Advantages of composites:

1. Specific stiffness and specific strength:

The composite materials have high specific stiffness and strengths. Thus, these material offer better properties at lesser weight as compared to conventional materials. Due to this, one gets improved performance at reduced energy consumption.

2. Tailorable design:

A large set of design parameters are available to choose from. Thus, making the design procedure more versatile. The available design parameters are: Choice of materials (fiber/matrix), volume fraction of fiber and matrix, fabrication method, layer orientation, no. of layer/laminae in a given direction, thickness of individual layers, type of layers (fabric/unidirectional) stacking sequence. And component can be designed to have desired properties in specific directions.

3. Fatigue Life:

The composites can with stand more number of fatigue cycles than that of aluminum. The critical structural components in aircraft require high fatigue life. The use of composites in fabrication of such structural components is thus justified.

4. Dimensional Stability:

Strain due to temperature can change shape, size, increase friction, wear and thermal stresses. The dimensional stability is very important in application like space antenna. For composites, with proper design it is possible to achieve almost zero coefficient of thermal expansion.

5. Corrosion Resistance:

Polymer and ceramic matrix material used to make composites have high resistance to corrosion from moisture, chemicals.

6. Cost effective Fabrication: The components fabricated from composite are cost effective with automated methods like filament winding, pultrusion and tape laying. There is a lesser wastage of the raw materials as the product is fabricated to the final product size unlike in metals.

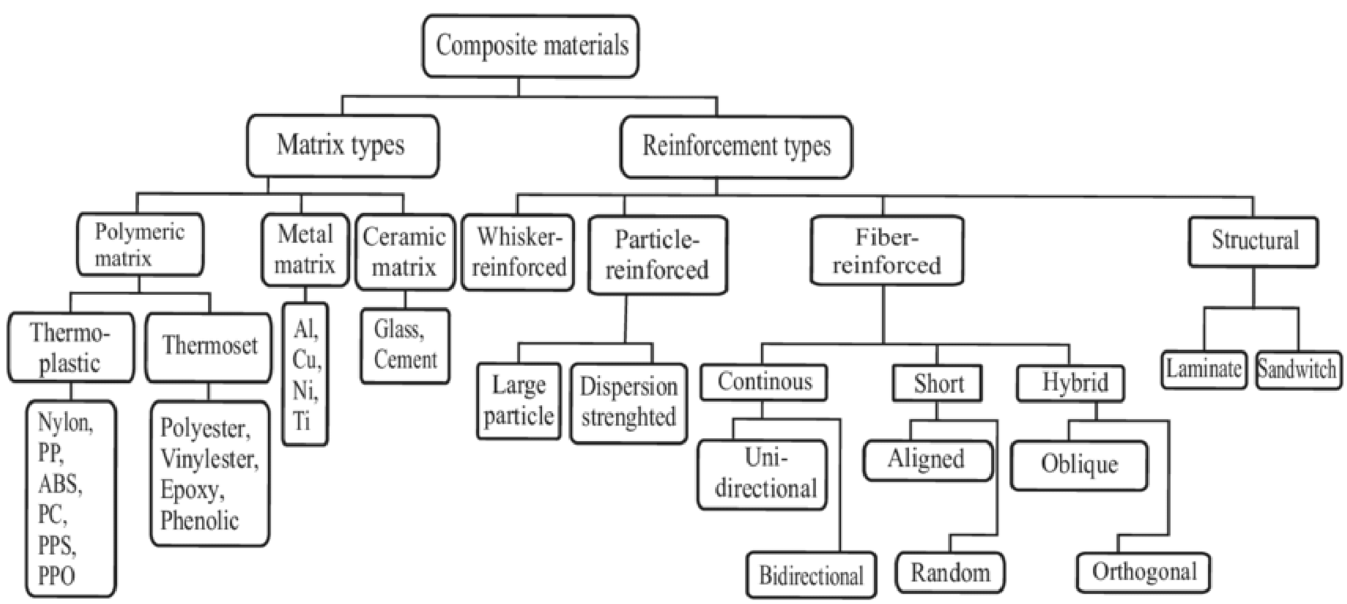
7. Conductivity:

The conductivity of the composites can be achieved to make it a insulator or a highly conducting material. For example, Glass/polyesters are non conducting materials. These materials can be used in space ladders, booms etc. where one needs higher dimensional stability, whereas copper matrix material gives a high thermal conductivity.

The disadvantages of Composites are:

1. Some fabrics are very hard on tooling.
2. Hidden defects are difficult to locate.
3. Inspection may require special tools and processes.
4. Filament-wound parts may not be repairable. Repairing may introduce new problems.
5. High cost of raw materials.
6. High initial cost of tooling, production set-up, etc.
7. Labour intensive. 8. Health and safety concerns.
9. Training of the labour is essential.
10. Environmental issues like disposal and waste management.
11. Reuse of the materials is difficult.
12. Storage of frozen pre-pregs demands for additional equipments and adds to the cost of production.
13. Extreme cleanliness required.
14. The composites, in general, are brittle in nature and hence easily damageable.
15. The matrix material is weak and hence the composite has low toughness.
16. The transverse properties of lamina or laminate are, in general, weak.
17. The analysis of the composites is difficult due to heterogeneity and orthotropy.

Classifications of Composites:



FIBER-REINFORCED COMPOSITES: Most fiber-reinforced composites provide improved strength and other mechanical properties and strength-to- weight ratio by incorporating strong, stiff but brittle fibers into a softer, more ductile matrix. The matrix material acts as a medium to transfer the load to the fibers, which carry most off the applied load, also provides protection to fibers from external loads and atmosphere.

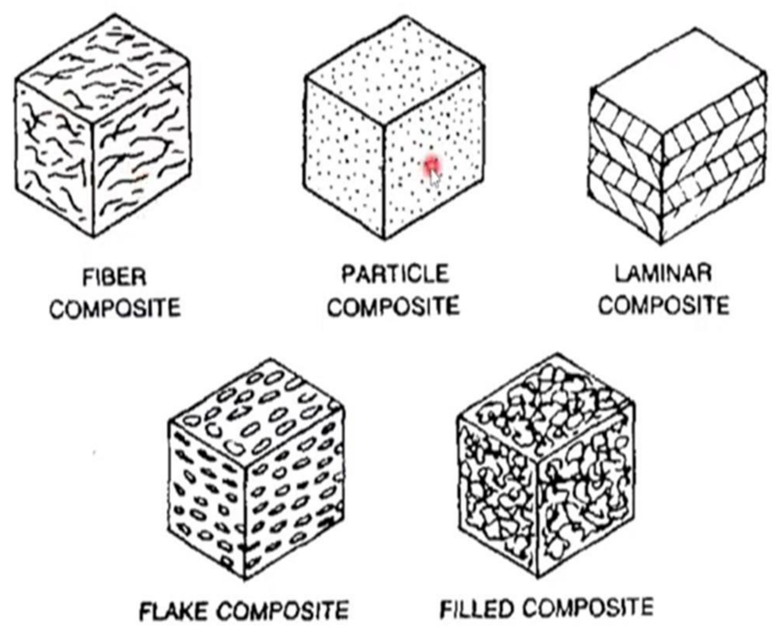
These composites are classified as either continuous or discontinuous.

Generally, the highest strength and stiffness are obtained with continuous reinforcement. high specific strength and moduli have been produced that utilize low density fillers and matrix materials.

Discontinuous fibers are used only when manufacturing economics dictate the use of a process where the fibers must be in this form.

The mechanical properties of fiber-reinforced composites depend not only on the properties of the fiber but also on the degree of which an applied load is transmitted to the fibers by the matrix phase.

Length of fibers, their orientation and volume fraction in addition to direction of external load application affects the mechanical properties of these composites.



SANDWICH STRUCTURES:

consist of thin layers of a facing material joined to a light weight filler material. Neither the filler material nor the facing material is strong or rigid, but the composite possesses both properties. Example: corrugated cardboard.

The faces bear most of the in-plane loading and also any transverse bending stresses. Typical face materials include Al-alloys, fiber-reinforced plastics, titanium, steel and plywood. The core serves two functions – it separates the faces and resists deformations perpendicular to the face plane; provides a certain degree of shear rigidity along planes that are perpendicular to the faces.

Typical materials for core are: foamed polymers, synthetic rubbers, inorganic cements, balsa wood. Sandwich structures are found in many applications like roofs, floors, walls of buildings, and in aircraft for wings, fuselage and tailplane skins.

Advantages and Limitations of Composites Materials

Advantages of Composites

The advantages exhibited by composite materials, which are of significant use in aerospaceindustry are as follows:

• High resistance to fatigue and corrosion **degradation**.

• High 'strength or stiffness to weight' ratio. As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.

• Due to greater **reliability**, there are fewer inspections and structural repairs.

• Directional **tailoring capabilities** to meet the design requirements. The fibre pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.

• Fiber to fiber redundant load path.

• Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.

• It is easier to achieve smooth **aerodynamic profiles** for drag reduction. Complex double- curvature parts with a smooth surface finish can be made in one manufacturing operation.

• Composites offer improved **torsion stiffness**. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.

• High resistance to impact damage.

• Thermoplastics have rapid process cycles, making them attractive for high volume commercial applications that traditionally have been the domain of sheet metals. Moreover, thermoplastics can also be reformed.

• Like metals, thermoplastics have indefinite shelf life.

• Composites are **dimensionally stable** i.e. they have low thermal conductivity and low coefficient of thermal expansion. Composite materials can be tailored to comply with a broad range of thermal expansion design requirements and to minimize thermal stresses.

• Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.

• The improved **weather ability** of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.

• Close tolerances can be achieved without machining.

• Material is reduced because composite parts and structures are frequently built to shape rather than machined to the required configuration, as is common with metals.

• Excellent heat sink properties of composites, especially Carbon-Carbon, combined with their lightweight have extended their use for aircraft brakes.

• Improved friction and wear properties.

• The ability to tailor the basic material properties of a Laminate has allowed new approaches to the design of **aero elastic flight structures**.

The above advantages translate not only into airplane, but also into common implements and equipment such as a graphite racquet that has inherent damping, and causes less fatigue and pain to the user.

Limitations of Composites

Some of the associated disadvantages of advanced composites are as follows:

- High cost of raw materials and fabrication.
- Composites are more brittle than wrought metals and thus are more easily damaged.
- Transverse properties may be weak.
- Matrix is weak, therefore, low toughness.
- Reuse and disposal may be difficult.
- Difficult to attach.
- Repair introduces new problems, for the following reasons:
  - Materials require refrigerated transport and storage and have limited shelf life.
  - Hot curing is necessary in many cases requiring special tooling.
  - Hot or cold curing takes time.
  - Analysis is difficult.
  - Matrix is subject to environmental degradation.
- Long term service experience of composite material environment and **durability behavior**

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 are a number of types of smart material, 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.

Temperature-responsive polymers are materials which undergo changes upon temperature.

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.

The properties that distinguished them from other materials,

Transiency: they can respond to various types of external stimulus, immediacy: the response time very less, self-actuation: this is the ability to change their appearance and shape, selectivity: the response is divided and expected,