TVET CERTIFICATE III in Welding

WLDMA301

MATERIALS

Select materials

Competence

Credits: 6

Learning hours: 60

Sector: Welding and Manufacturing
Sub-sector: Welding

Module Note Issue date: June, 2020

Purpose statement

This general module describes the performance outcomes, skills and knowledge required to differentiate size and shape of materials, identify properties of materials and to identify the area of application of welding materials.

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Total Number of Pages: 36 pages

Learning Unit 1: Identify types of materials

LO 1.1: Classify materials

Most materials fall into one of three classes that are based on the atomic bonding forces of a particular material. These three classifications are **metallic**, **ceramic** and **polymeric**, different materials can be combined to create a composite material. Materials are organized into groups based on their chemical composition or certain physical or mechanical properties. The following table illustrates the groups of materials and their types.

Metals	Polymeric
• Ferrous metals and alloys (irons, carbon steels, alloy steels, stainless steels, tool and die steels) • Nonferrous metals and alloys (aluminum, copper, magnesium, nickel, titanium, precious metals, refractory metals, superalloys)	• Thermoplastics plastics • Thermoset plastics • Elastomers
Ceramics	**Composites**
• Glasses • Glass ceramics • Graphite • Diamond	• Reinforced plastics • Metal-matrix composites • Ceramic-matrix composites • Sandwich structures • Concrete

1. Metals: Metals account for about two thirds of all the elements and about 24% of the mass of the planet. Metals have useful properties including:

- Strength
- Ductility
- High melting points
- Thermal and electrical conductivity
- Toughness

2. Ceramics: is fabricated into products through the application of heat, and displays such characteristic properties as:

- Hardness,
- strength,
- low electrical conductivity,
- brittleness.

" The word ceramic comes from Greek word "**keramikos**", which means "**pottery**." Ceramics are typically crystalline in nature and are compounds formed between metallic and nonmetallic elements such as aluminum and oxygen (alumina-Al_2O_3), calcium and oxygen (calcia - CaO), and silicon and nitrogen (silicon nitride-Si_3N_4).

(This picture shows different types of ceramics)

The broad categories or segments that make up the ceramic industry can be classified as:

- **Structural clay products**: brick, sewer pipe, roofing and wall tile, flue linings, etc.
- **White wares:** dinnerware, floor and wall tile, electrical porcelain, etc.
- **Refractories**: brick and monolithic products used in metal, glass, cements, ceramics, energy conversion, petroleum, and chemicals industries.
- **Glasses: flat** glass (windows), container glass (bottles), pressed and blown glass (dinnerware), glass fibers (home insulation), and advanced/specialty glass (optical fibers))
- **Abrasives:** (natural (garnet, diamond, etc.) and synthetic (silicon carbide, diamond, fused alumina) etc. Abrasives are used for grinding, cutting, polishing, lapping, or pressure blasting of materials.
- **Cements**: for roads, bridges, buildings, dams, and etc.)

Advanced ceramics

- **Structural** (wear parts, bioceramics, cutting tools, and engine components)
- **Electrical** (capacitors, insulators, substrates, integrated circuit packages, piezoelectrics, magnets and superconductors)
- **Coatings** (engine components, cutting tools, and industrial wear parts)
- **Chemical and environmental** (filters, membranes, catalysts, and catalyst supports)

Briefly though, the two most common chemical bonds for ceramic materials are covalent and ionic. Covalent and ionic bonds are much stronger than in metallic bonds and, generally speaking, this is why ceramics are brittle and metals are ductile.

3. Polymers

A polymeric solid can be thought of as a material that contains many chemically bonded parts or units which themselves are bonded together to form a solid. The word polymer literally means "**many parts**." Two industrially important polymeric materials are **plastics** and **elastomers**.

- **Plastics:** are a large and varied group of synthetic materials which are processed by forming or molding into shape. Just as there are many types of metals such as aluminum and copper, there are many types of plastics, such as polyethylene and nylon.
- **Elastomers** or **rubbers:** can be elastically deformed a large amount when a force is applied to them and can return to their original shape when the force is released.

Properties of polymers:

- Resist atmospheric and other forms of corrosion
- Offer good compatibility with human tissue

- Exhibit excellent resistance to the conduction of electrical current
- Less dense than metals or ceramics

(Picture showing different types of polymers)

Rubber is a natural occurring polymer. However, most polymers are created by engineering the combination of hydrogen and carbon atoms and the arrangement of the chains they form. The polymer molecule is a long chain of covalent-bonded atoms and secondary bonds then hold groups of polymer chains together to form the polymeric material.

Polymers are primarily produced from petroleum or natural gas raw products but the use of organic substances is growing. The super-material known as Kevlar is a man-made polymer. Kevlar is used in bullet-proof vests, strong/lightweight frames, and underwater cables that are 20 times stronger than steel.

4. Composites

A composite is commonly defined as a combination of two or more distinct materials, each of which retains its own distinctive properties, to create a new material with properties that cannot be achieved by any of the components acting alone. Using this definition, it can be determined that a wide range of engineering materials fall into this category.

For example, concrete is a composite because it is a mixture of Portland cement and aggregate. Fiberglass sheet is a composite since it is made of glass fibers imbedded in a polymer.

Composite materials have two phases:

- The reinforcing phase is the fibers, sheets, or particles that are embedded in the matrix phase.
- The reinforcing material and the matrix material can be metal, ceramic, or polymer.

Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile, or tough, material.

Content/Topic 1.2: Types of metals

A. Ferrous metals

Ferrous metals : When a metal contains iron, it is known as a ferrous metal. The iron imparts magnetic properties to the material and also makes them prone to corrosion.

Iron production

Iron ores are rocks and minerals from which metallic iron can be economically extracted. The ores are usually rich in iron oxides and vary in color from dark grey, bright yellow, deep purple, to rusty red. Iron ore is the raw material used to make pig iron, which is one of the main raw materials used to make steel. Ninety-eight percent of the mined iron ore is used to make steel.

- Iron is produced by converting iron ore to pig iron using a blast furnace.
- Pig iron is the intermediate product of smelting iron ore with coke, usually with limestone as a flux.
- Pig iron has very high carbon content, typically 3.5–4.5%, which makes it very brittle and not useful directly as a material except for limited applications.
- From pig iron, many other types of iron and steel are produced by the addition or deletion of carbon and alloys.

Ferrous metals include all forms of iron and iron-base alloys, with small percentages of carbon (steel, for example), and/or other elements added to achieve desirable properties.

Examples: carbon steels, alloy steels, cast iron, wrought iron, and tool steels

1. carbon steels: is composed of iron and carbon in varying proportions, steels are classified according to their carbon content as illustrated in the following table:

Steel Types	Carbon Content in %	Properties	Forms	Uses
Low carbon steel.	0-0.18	-Soft, ductile, malleable but not strong. -Does not crack	Available in rods, bars and sheets	-Suitable for deep pressings -Stampings are used for car bodies

Mild Steel	0.25-0.3	-Most common of all types of steels. -Machines readily. -It can cast, forged, and welded. -It corrodes in the atmosphere.	Obtained in rod, wires, sheets and various sections (e.g: T, angle)	For construction purposes and general workshop use.
Medium-Carbon Steel	0.4-0.6	-Machines readily -Can be forged and welded -When properly heat-treated, it is hard, ductile and strong	Available in rods, bars, flats	-Agriculture tools -hammer heads -rivets sets -Forged steel vice bodies
High-Carbon Steel	0.7-1.4	-Less ductile but combines hardness with high strength. -Hard but can be heat-treated. -Machines well. -Can be welded -Those with carbon content1.0% and above are the cast or tool steels	Usually available in short lengths of rod in various sections (e.g: round, square hexagon, octagon)	-Suitable for all kinds of cutting tolls as shown: -0.7% carbon: cold chisels, punches -0.9% carbon: lathe tools, milling cutters, saw blades -1.0% carbon: drills, taps, dies -1.2 % carbon: carpenter's chisels, plane blades -1.3% carbon: engineer's files, scrapers, ball bearing


(Low carbon steel bars)

2.<u>Alloy steels</u>

This type of metal contains multiple elements to enhance various properties. Metals such as **manganese, titanium, copper, nickel, silicon, vanadium, cobalt, molybdenum, tungsten and aluminum** may be added in different proportions.

This improves steel's:

- hardenability
- weld ability
- corrosion resistance
- ductility
- formability.

Applications for alloy steels are:

- electric motors
- bearings
- heating elements
- springs
- gears
- pipelines

Examples of alloy steels:

- **Stainless steel:** Stainless steel contains high amounts of chromium. This is why it has 200 times higher resistance to corrosion than mild steel. It makes it the ideal candidate to manufacture kitchen utensils, piping, surgical and dental equipment. Also, as no coating is necessary, you can have a metallic look like you want with the right surface finish.
- **Tool steel:** Tool steels are used for making **cutting and drilling tools**. Their high hardness makes them an ideal choice for these applications. They contain molybdenum, vanadium, cobalt, and tungsten as constituent metals.

(Shock –resisting tool steel in use)

3.Cast Iron

alloy of **iron** that contains 2 to 4 percent carbon, along with varying amounts of silicon and manganese and traces of impurities such as sulfur and phosphorus. It is made by reducing **iron** ore in a blast furnace

Types of cast iron

- White cast iron
- Grey cast iron
- Malleable cast iron
- Ductile cast iron

White cast iron

When the white cast iron is fractured, **white colored cracks** are seen throughout because of the presence of carbide impurities. White cast iron is **hard** but **brittle**. It has lower silicon content and low melting point

Grey cast iron

Grey is the most versatile and widely used cast iron. The presence of carbon leads to formation of graphite flakes that does not allow cracks to pass through, when the material breaks. Instead, as the material breaks the graphite initiates numerous new cracks. The fractured cast iron is **greyish** in color, which also gives it the name.

Malleable cast iron

Malleable cast iron is basically white iron that undergoes heat treatment to convert the carbide into graphite. The resultant cast iron has properties that vary from both **grey** and **white** cast iron.

Ductile cast iron

Ductile cast iron is yet another type of ferrous alloy that is used as an engineering material in many applications. To produce ductile iron, small amount of **magnesium is added** to the molten iron, which alters the graphite structure that is formed.

4.<u>Wrought Iron</u>:

Is the purest of all ferrous metals containing about 99.9 percent iron. Because of this it has special qualities, **being strong, tough and easily to machine**. It resists to corrosion and its ability to withstand shock makes it is suitable for use as haulage gear and couplings.

B. <u>Non-ferrous metals</u>

Non-ferrous metals do not contain iron; examples of non-ferrous metals include:

- Aluminiun, lead, zinc and tin (in pure state)
- Bronze and brass (in combination of two or more these elements of above)

In non-ferrous we have:

1. <u>Aluminium</u>: derives primarily from its ore bauxite. It is light, strong, and functional. It is the most widespread metal on Earth and its use has permeated applications everywhere.

Aluminium properties:

- durability,
- light weight,
- corrosion resistance,
- electrical conductivity
- ability to form alloys with most metals.
- It also doesn’t magnetize and is easy to machine.

<u>Uses:</u> Aluminium is used in a huge variety of products including cans, foils, kitchen utensils, window frames, beer kegs and aeroplane parts.

2.__**copper and its alloys**__

Copper is **brownish-pink** in color and has a melting temperature 1080^0c. It is used in pure state and in making alloys such as brass.

Copper has the following properties:

- Good electric conductivity
- High thermal conductivity
- A remarkable mixture of strength and plasticity
- Corrosion resistance in many environments
- Attractive finish when polished

3.__**Brass**__**:** is an alloy of **copper(Cu)** and **zinc(Zn)** in varying proportions, with not more than 5or 6 per cent other metals.

- 10-20% Zn alloys are known as gilding metals that are used in the jewelry industry and in the production of heat exchangers.
- 30% Zn alloys are called cartridge brass for a pretty self-explanatory reason.

Adding other alloying elements can further improve brass's properties. Sn(Tin) and Al(Aluminium), for example, increase its corrosion resistance in seawater.

There two types of brasses: **Single Phase Brass** and **Double Phase Brass**

__**Single Phase Brass**__: contain Zn up to 37%. Those are called alpha brasses. Single phase brasses have a homogeneous crystal structure.

- Such brasses are softer and have higher ductility. Those qualities make alpha brasses suitable for cold working, drawing, bending, etc

(Bullets container made in single phase brass)

Applications of **Single Phase Brass**:
- Jewellery,
- art
- deep drawn parts (cutlery, musical instruments, etc.)
- ammunition(bullets) cartridges.

Double Phase Brass: Double phase brasses, also known as **duplex brasses**, contain both the α and β phases. Alpha-beta brasses have a zinc content up to 45%. Anything above is beta brass but it finds a lot less use.

Double phase brass is more affordable(cheap) than single phase brass because of the larger amount of zinc used in it. At the same time, it's more prone (disposed to) to corrosion. Still, the chemical composition leads to greater strength and hardness.

Therefore, double phase brass is suitable for **hot forming** and c**asting**. Extrusion, stamping and die-casting are usable methods with this type of metal.

Applications **Double Phase Brass**:
- Heat exchangers,
- Capacitors,
- Parts made by automatic cutting benches, etc.

4.Bronze: is a copper and Tin alloy

Applications:
- Springs,
- Coins,
- Arts bronze sheets,
- Parts of pumps,
- Pressure-resistant castings,
- Bearings, etc.


(Tin bronze bowl)

The applications depend on the % of Sn used in the alloy. The maximum amount of Sn in alloys suitable for cold working is around 7%.

Aluminium Bronze: Aluminium bronzes have similar characteristics to tin bronzes. These alloys, mostly, have a single phase and are suitable for cold forming. This makes aluminium bronze a popular choice as a coin material.

Applications of Aluminium Bronze:

- Coins
- Ship parts
- Marine hardware
- Sleeve bearings
- Pumps
- Valves, etc.

5.Lead: is the heaviest of the common metals and has a low melting point(330^{0}C), it is in **blue grey** color

6.Zinc: is a **bluish-white** metal, which melts at 422^{0}C, you often see zinc used on iron or steel in the form of a protective coating called galvanizing.

Applications of Zinc:

- Zinc is also used in
- Soldering fluxes
- Die castings
- Used as an alloy in making brass and bronze.

Properties of metals

- **Color:** this helps in identifying metals and enhances their appearance when polished. It is useful in beaten metal work and jewelers.
- **Fusibility:** the characteristic of becoming liquid when a metal is heated.
- **Conductivity:** the easy with which a metal allows heat or electricity to flow through it.
- **Hardness:** the ability of a metal to resist to scratching and wear.
- **Ductility:** the ability of a metal to be stretched cold without breaking

- **Toughness:** this enables the material to be bent or twisted to resist to shock without breaking.
- **Malleability:** malleable materials can be hammered, rolled or extruded without breaking.
- **Elasticity:** is the ability of a metal to go back to its original shape or size after being stretched, compressed or deformed, as in spring for example.

- Content/Topic 2: types of plastics

The polymer plastics can be divided into two classes, t**hermoplastics** and **thermosetting plastics**, depending on how they are structurally and chemically bonded.

a) Thermoplastics: Thermoplastic polymers comprise the four most important commodity materials: polyethylene, polypropylene, polystyrene and polyvinyl chloride. There are also a number of specialized engineering polymers.

The term 'thermoplastic' indicates that these materials melt on heating and may be processed by a variety of molding and extrusion techniques.
Examples of thermoplastic materials are polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyamides, polyesters, and polyurethanes. High-**temperature** thermoplastics include polyetherether ketones, liquid crystalline polymers, polysulfones, and polyphenylene sulfide.


(A technology for strong moldable materials)

b) Thermosetting plastics: Thermosetting polymers cannot be melted or remolded. Thermosetting polymers include alkyds, amino and phenolic resins, epoxies, polyurethanes, and unsaturated polyesters. Common **examples** of **thermoset plastics** include epoxy, silicone, polyurethane and phenolic.

(PVC: Polyvinyl chloride)

LO 1.2: Choose Materials

The choice of materials for a project requires considerations of aesthetic appeal and initial and ongoing costs, life cycle assessment considerations such as Material Composition, Shape Size.

Content/Topic 1: Material Composition

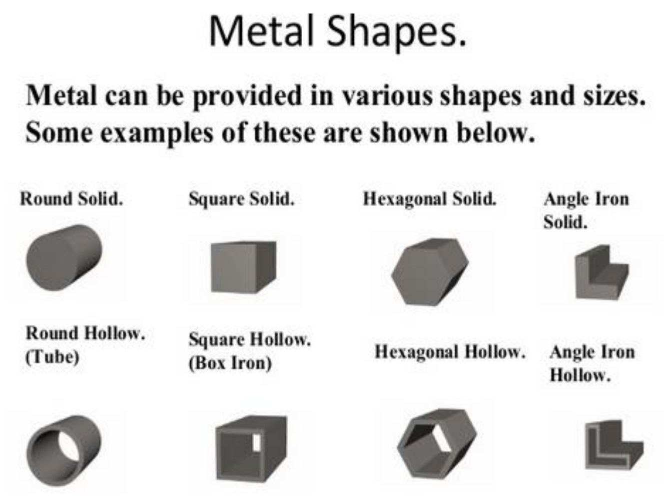
To understand more about the materials in each part, it is useful to assign a generic material type for each homogeneous material.

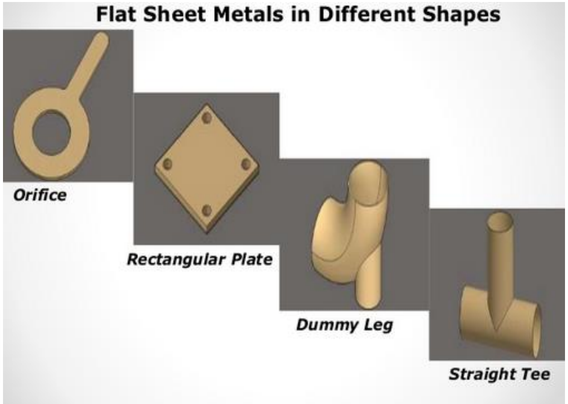
Examples include:

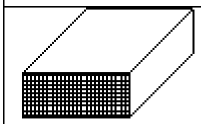
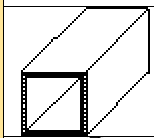
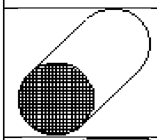
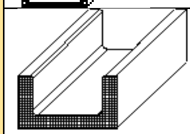
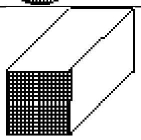
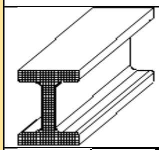
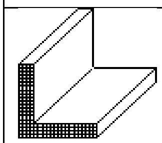
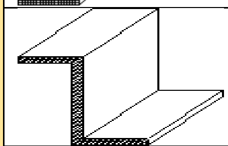
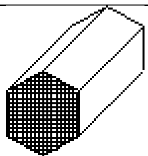
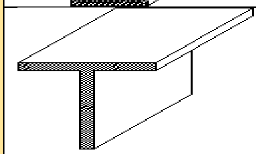
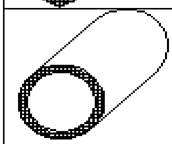
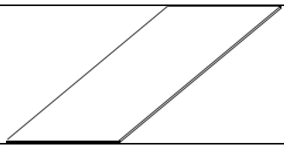
- Metal
- Plastic
- metal composite
- Dyed textile
- Solvent
- Wood
- Fabric or fiber
- Glass
- Foam
- Glue

- Content/Topic 2: Shape and shape

Choosing materials according to their shape is necessary by referring to the job you have.





Material shape	***Size specification***		***Material shape***	***Size specification***
	**Flat-bar:** Thickness × Width × Length			**Square-tubing:** Thickness × Width × Length
	**Round-bar:** Diameter × Length			**Channel-Bar:** Width × Height × Length
	**Square-bar:** Width × Length			**I-Beam:** Length × Thickness × pounds
	**Angle-bar:** Thickness × Width × Length			**Z-Bar:** Width × Length
	**Hexagon-bar:** Diameter × Length			**T-Bar:** Width × Length
	**Pipe:** Diameter × Schedule × Length x 20 is thinner than x 40			**Metal Sheet:** Gauge × Width × Length

LO 1.3: Identify Materials

- Content/Topic 1: Metals Differentiation

Metals are differentiated: **Colors**, **Mass**, **Soundness**, **Chip removal** and **magnetic test**

1. Colors: Sometimes it is possible to identify metals by their surface appearance. The following table indicates the surface colors of some of the more common metals.

Metals	Color of unfinished, unbroken surface	Color and structure of newly fractured surface	Color of freshly filed surface
1. White cast iron	Dull gray	Silvery white, crystalline	Silvery white
2. Gray cast iron	Dull gray	Dark gray, crystalline	Light silvery gray
3. Malleable iron	Dull gray	Dark gray, finely crystalline	Light silvery gray
4. Wrought iron	Light gray	Bright gray	Light silvery gray
5. Low-carbon and cast steel	Dark gray	Bright gray	Bright silvery gray
6. High-carbon steel	Dark gray	Light gray	Bright silvery gray
7. Stainless steel	Dark gray	Medium gray	Bright silvery gray
8. Copper	Reddish brown to green	Bright red	Bright copper color
9. Brass and bronze	Reddish yellow, yellow green or brown	Red to yellow	Reddish yellow to yellowish white
10. Aluminum	Light grey	White, finely crystalline	White
11. Monel metal	Dark grey	Light gray	Light gray
12. Nickel	Dark grey	Off-white	Bright silvery white
13. Lead	White to grey	Light gray, crystalline	White

A surface examination does not always provide enough information for identification but should give us enough information to place the metal into a class.

- Cast iron and malleable iron usually show evidence of the sand mold.
- Low-carbon steel often shows forging marks.
- High-carbon steel shows either forging or rolling marks.

Feeling the surface may provide another clue.

- Stainless steel is slightly rough in the unfinished state.
- Surfaces of wrought iron, copper, brass, bronze, nickel, and Monel are smooth.
- Lead also is smooth but has a velvety appearance.

2. <u>Mass</u>: is both a property of a physical body and a measure of its resistance to acceleration (a change in its state of motion) when a net force is applied. An object's mass also determines the strength of its gravitational attraction to other bodies.

3. <u>Soundness</u>: The soundness test determines an aggregate's resistance to disintegration by weathering and, in particular, freeze-thaw cycles.

4. <u>Chip removal</u>: The chip test is made by removing a small amount of material from the test piece with a sharp, cold chisel. The material removed varies from small, broken fragments to a continuous strip. The chip may have smooth, sharp edges; it maybe coarse grained or fine-grained; or it may have saw like edges.

Metals	Chip characteristics
1. White cast iron	Chips are small, brittle fragments. Chipped surfaces not smooth
2. Gray cast iron	Chips are 1/8 inch in length. Metals not easily chipped, therefore, chips break off and prevent smooth cut.

3. Malleable iron	Chips vary from ¼ to 3/8 inch in length (larger than chips form cast iron). Metal is tough and hard to chip
4. Wrought iron	Chips have smooth edges. Metal is easily cut or chipped, and a chip can be made as a continuous strip.
5. Low-carbon and cast steel	Chips have smooth edges. Metal is easily cut or chipped, and a chip can be taken off as a continuous strip.
6. High-carbon steel	Chips show a fine- grain structure. Edges of chips are lighter in color than chips of low carbon steel. Metal is hard, but can be chipped in a continuous strip
7. Copper	Chips are smooth, with saw tooth edges where cut. Metal is easily cut as a continuous strip.
8. Brass and bronze	Chips are smooth, with saw tooth edges. These metals are easily cut, but chips are more brittle than chips of copper. Continuous strip is not easily
9. Aluminum and aluminum alloys	Chips are smooth, with saw tooth edges. A chip can be cut as continuous strip.
10. Monel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
11. Nickel	Chips have smooth edges. Continuous strip can be cut. Metal chips easily.
12. Lead	Chips of any shape may be obtained because the metal is so soft that can be cut with a knife.

5. <u>MAGNETIC TEST</u>

The use of a magnet is another method used to aid in the general identification of metals. Remember that ferrous metals, being iron-based alloys, normally are magnetic, and nonferrous metals are nonmagnetic. This test is not 100-percent accurate because some stainless steels are nonmagnetic. In this instance, there is no substitute for experience.

Learning Unit 2: Differentiate size and shape of materials

LO 2.1 – Identify shapes of materials

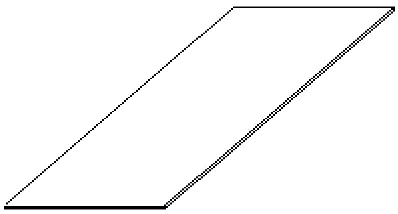
- Content/Topic 1: Types and sizes of profiles

a) Sheet metal: a sheet metal is a piece of metal whose thickness is between (0.15 – 6.35) cm thickness as illustrated as under:

Thickness in mm	1	1.2	1.5	1.7	2	2.5	2.8	3	3.4
	3.8	4.2	4.6	5	5.3	5.7	6	6.2	6.35

Sheet metal is formed by an industrial process into thin, flat pieces. Sheet metal is one of the fundamental forms used in metalworking, and it can be cut and bent into a variety of shapes. Countless everyday objects are fabricated from sheet metal. Thicknesses can vary significantly; extremely thin sheets are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate steel or "structural steel".

Sheet metal is available in flat pieces or coiled strips. The coils are formed by running a continuous sheet of metal through a roll slitter.

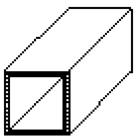


Metal Sheet: Gauge × Width × Length

b) Tubes: Tubes: Tubes are metals shape which can be square or rectangle form and it contains a hole inside passing through, the sizes of Tubes exist are described as under:

i. **Square tubes size:**

Tubes Ø in mm	6	10	13	16	20	25	28	30	35	40
	45	50	54	60	67	73	76	80	85	90



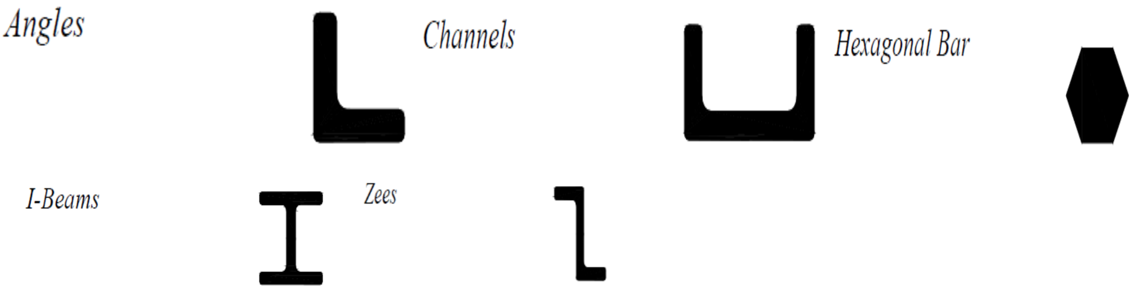
Square-tubing: Thickness × Width × Length

Tubes size in mm	15x10	20x10	20x15	25x10	25x15	25x20	30x10	30x15	30x20	30x25
	35x20	35x25	36x11	40x10	40x15	40x20	40x25	40x30	45x20	45x25
	50x25	50x30	50x34	50x35	50x40	55x34	60x20	60x25	60x30	60x33
	60x50	67x35	70x20	70x30	70x35	70x40	70x45	70x50	75x20	75x50
	80x40	80x50	80x60	90x40	90x45	90x50	100x20	100x40	100x50	100x60
	120x40	120x50	120x60	120x80	125x75	140x40	140x70	140x80	150x50	150x80

	34x20	35x15	50x10	50x20	60x35	60x40	80x20	80x30	100x80	110x70

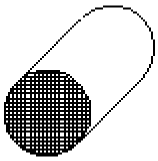
i. **Rectangle tubes size:**

c) Profiles: a profile is a subset internal to a specification. Aspects of a complex technical specification may necessary have more than one interpretation, and there are probably many optional features. these aspects constitute a profile of the standard. Two implementations engineered from the same description may not interoperate due to having a different profile of the standard. These use of profile in these ways can force one interpretation, or create the factor standards from official standard. Engineers can design by using profile to ensure interoperability.
Profile shapes are:
Standard Structural Shapes (Profiles Forms Standard)



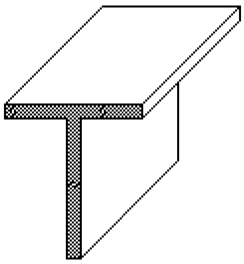
d) Round bar: is a kind of tool steel which is measured in dimeter:

Round bar Ø in mm	6	8	10	12	14	16	18	20	22	25	28	32	36	40	50



Round-bar: Diameter × Length

e) Iron Tee: Is a beam or bar shaped like the letter T which is made with iron in its composition.



T-Bar: Width × Length

All sizes of tee bars are described as under:

Equal tee section

Size in mm	20x20x3	20x20x4	25x25x3	25x25x3.5	25x25x4	30x30x3
	40x40x3	40x40x4	40x40x5	45x45x2.5	50x50x3	50x50x4
	60x60x3	60x60x4	60x60x5	60x60x6	70x70x7	80x80x8
	100x100x10	100x100x13	140x140x15	30x30x4	35x35x4	50x50x5
	50x50x4	90x90x9	100x100x8			

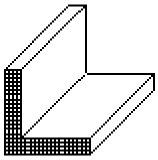
Unequal tee section

	20x40x4	25x50x5	30x60x5.5	35x70x6

Size in mm	40x60x4	40x80x7	50x100x8.5	60x120x10

f) Angle iron: an iron of steel bar, brace, or created in the form of an angle, also called able bar, L-bar, L beam, a piece of structural iron or steel having a cross section in the form of L.

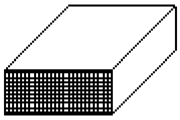
Size in mm	25x25x2	40x40x4	50x60x4	50x50x5	50x50x6
	60x60x5	75x75x6	80x80x6	80x80x8	



Angle-bar: Thickness × Width × Length

g) Flat bar: are rectangle section with square edges varying in sizes. This cost – effective steel product is suitable for a wide variety of application and is distributed into the construction, engineering, manufacturing, mining, grating, fabrication, and many others industries.

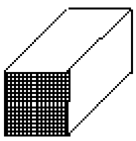
Thickness in mm	20	25	30	35	40	45	50	55	60	65	70
	75	80	90	100	110	120	130	150	160	140	



Flat-bar: Thickness × Width × Length

g) Square bar: is one of the hot rolled steel bars (manufactured bar), all our square steel bars are available in mild steel, high yield steel, carbon steel.

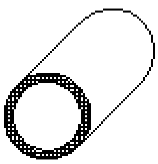
Thickness in mm	10x10	12x12	14x14	16x16	17x17	20x20	25x25
	32x32	40x40	42x42	50x50	53x53	56x56	63x63



Square-bar: Width × Length

i) Pipes: : the pipes sizes are given as the nominal tube size. for size, up to 12 inches the approximately size (clearance) of the pipe diameter is given by multiplying by 25 because 1 inch is equal to 25 mm.

Diameter in mm	8	10	13.5	17	21	26	32.8	42	48	59	72	87.5
	140	165	190	215	240	268	294	318	350	400	450	500
	750	800	850	900	1050	1200	112.5	125	`650	700	100	600



Pipe: Diameter × Schedule × Length x 20 is thinner than x 40

LO 2.2 – Identify size of materials

- Content/Topic 1: Dimensions of materials

Dimensions of materials: **Length, width, and height** are measurements that allow us to indicate the volume of geometric bodies.

- **Length** is a measure of how long an **object** is or the distance between two points
- **Width:** is defined as the quality of being wide, or the measurement of distance from side to side.
- **height:** is used when there is a base from which vertical measurements can be taken.

Different measuring tools used in order to know the dimensions of materials:

- Tape measure
- Vernier caliper
- Steel ruler
- Square
- Protractor

Learning Unit 3: Identify properties of materials

LO 2.1– Identify Physical properties

- Content/Topic 1: Physical properties

In physical properties include:

- Melting point
- Mass
- Heat treatment

A. Melting point: is the temperature at which the material changes state from solid to liquid. At the melting point the solid and liquid phase exist in equilibrium. The melting point of a substance depends on pressure and is usually specified at a standard pressure such as 1 atmosphere or 100 kPa.

B. Mass: is both a property of a physical body and a measure of its resistance to acceleration (a change in its state of motion) when a net force is applied. An object's **mass** also determines the strength of its gravitational attraction to other bodies. The basic SI unit of **mass** is the kilogram (kg).
C. Heat treatment: involves the use of **heating** or chilling, normally to extreme temperatures, to achieve the desired result such as hardening or softening of a material.

Heat treatment techniques include:

- Annealing
- Normalizing
- Quenching
- Case hardening
- Tempering
- Stress relieving

1. Annealing: consists of heating a metal to a specific temperature and then cooling at a rate that will produce a refined **microstructure**, either fully or partially separating the constituents. The rate of cooling is generally slow. Annealing is most often used to soften a metal for cold working, to improve machinability, or to enhance properties like **electrical conductivity**.

2. Normalizing: is a technique used to provide uniformity in grain size and composition (**equiaxing**) throughout an alloy. The term is often used for ferrous alloys that have been **austenized** and then cooled in open air. Normalizing not only produces pearlite, but also **martensit**e and sometimes **bainite**, which gives harder and stronger steel, but with less ductility for the same composition than full annealing.

3. Quenching
Quenching is a process of cooling a metal at a rapid rate. This is most often done to produce a **martensite** transformation. In ferrous alloys, this will often produce a harder metal, while non-ferrous alloys will usually become softer than normal

4. Case hardening: is a thermochemical diffusion process in which an alloying element, most commonly carbon or nitrogen, diffuses into the surface of a monolithic metal. The resulting interstitial solid solution is harder than the base material, which improves wear resistance without sacrificing toughness.

5. Tempering: Untempered martensitic steel, while very hard, is too brittle to be useful for most applications. A method for alleviating this problem is called tempering. Most applications require that quenched parts be tempered. Tempering consists of heating steel below the lower critical temperature, (often from 400 to 1105 ˚F or 205 to 595 ˚C, depending on the desired results), to impart some **toughness**. Higher tempering temperatures (may be up to 1,300 ˚F or 700 ˚C, depending on the alloy and application) are sometimes used to impart further ductility, although some yield **strength** is lost.

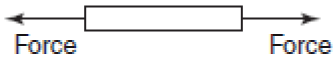
6. Stress relieving: is a technique to remove or reduce the internal stresses created in a metal. These stresses may be caused in a number of ways, ranging from cold working to non-uniform cooling. Stress relieving is usually accomplished by heating a metal below the lower critical temperature and then cooling uniformly.

- Content/Topic 2: Mechanical properties

In mechanical properties include:

- Tensile
- Compressive
- Torsion

a) Tensile strength:, is the maximum **stress** that a material can withstand while being stretched or pulled before breaking.



Examples:

- the rope or cable of a crane carrying a load is in tension
- rubber bands, when stretched, are in tension
- when a nut is tightened, a bolt is under tension

A tensile force, i.e. one producing tension, increases the length of the material on which it acts.
In **brittle** materials the ultimate tensile strength is close to the **yield point**, whereas in **ductile** materials the ultimate tensile strength can be higher

Two vises apply tension to a specimen by pulling at it, stretching the specimen until it fractures. The maximum stress it withstands before fracturing is its ultimate tensile strength.

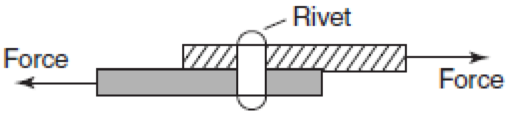
b. Compressive strength: Compression is a force that tends to squeeze or crush a material.

Examples of compressive strength:

- a pillar supporting a bridge is in compression
- the sole of a shoe is in compression
- the jib of a crane is in compression

A compressive force, i.e. one producing compression, will decrease the length of the material on which it acts.

c. Shear is a force that tends to slide one face of the material over an adjacent face.



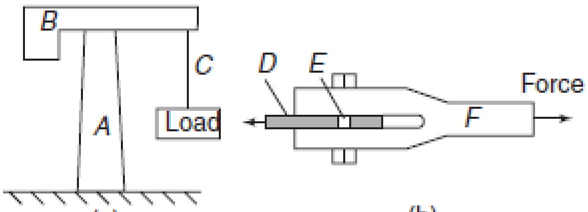
For examples:

- a rivet holding two plates together is in shear if a tensile force is applied between the plates—
- a guillotine cutting sheet metal, or garden shears, each provide a shear force
- a horizontal beam is subject to shear force
- transmission joints on cars are subject to shear forces

A shear force can cause a material to bend, slide or twist.

Exercise1.

Figure(a) represents a crane and Figure (b) a transmission joint. State the types of forces acting, labelled *A* to *F*.



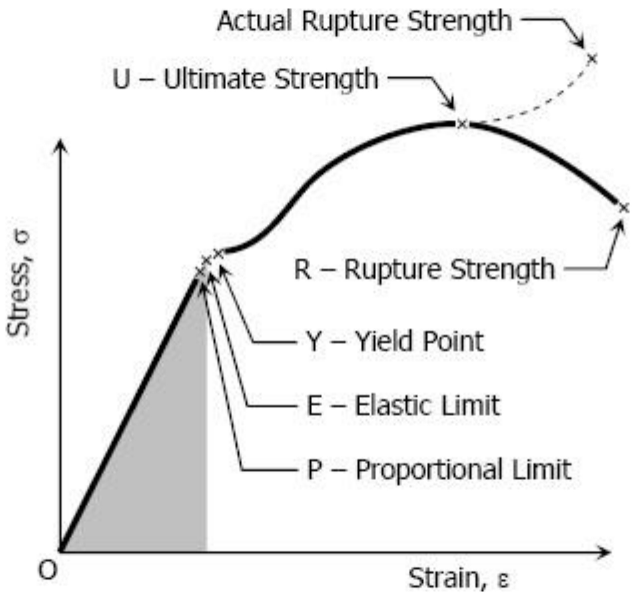
(a) (b)

Solution:

(a) For the crane, *A*, a supporting member, is in **compression**, *B*, a horizontal beam, is in **shear**, and *C*, a rope, is in **tension**.

(b) For the transmission joint, parts *D* and *F* are in **tension**, and *E*, the rivet or bolt, is in **shear**.

The stress strain curve



Stress

Forces acting on a material cause a change in dimensions and the material is said to be in a state of **stress**. Stress is the ratio of the applied force *F* to cross-sectional area *A* of the material. The symbol used for tensile and compressive stress is ***σ*** (Greek letter sigma). The unit of stress is the **Pascal, Pa,** where 1 Pa = 1 N/m2. Hence

$$\sigma = \frac{F}{A} \text{ Pa}$$

where **F** is the force in Newton's and **A** is the cross-sectional area in square meters.

For **tensile** and **compressive** forces, the cross-sectional area is that which is at right angles to the direction of the force.

For a **shear** force the shear stress is equal to $\frac{F}{A}$, where the cross-sectional area *A* is that which is parallel to the direction of the force. The symbol used for shear stress is the Greek letter
tau, ***τ***.

Exercise 2.

A rectangular bar having a cross-sectional area of 75 mm2 has a tensile force of 15 kN applied to it. Determine the stress in the bar.

Solution:

Cross-sectional area *A* = 75 mm2 = 75 × 10−6 m2
and force *F* = 15 kN = 15 × 103 N

$$\text{Stress in bar, } \sigma = \frac{F}{A} = \frac{15 \times 10^3 \text{ N}}{75 \times 10^{-6} \text{ m}^2}$$

$$= 0.2 \times 10^9 \text{ Pa} = \mathbf{200 \text{ MPa}}$$

Exercise 3.

A circular wire has a tensile force of 60.0 N applied to it and this force produces a stress of 3.06 MPa in the wire.

Determine the diameter of the wire.

Solution:

Force F = 60.0 N and

stress σ = 3.06 MPa = 3.06 × 106 Pa

$$\text{Since} \quad \sigma = \frac{F}{A}$$

$$\text{then area,} \quad A = \frac{F}{\sigma} = \frac{60.0 \text{ N}}{3.06 \times 10^6 \text{ Pa}}$$

$$= 19.61 \times 10^{-6} \text{ m}^2 = 19.61 \text{ mm}^2$$

$$\text{Cross-sectional area } A = \frac{\pi d^2}{4};$$

$$\text{hence } 19.61 = \frac{\pi d^2}{4}, \text{ from which,}$$

$$d^2 = \frac{4 \times 19.61}{\pi} \text{ from which, } d = \sqrt{\left(\frac{4 \times 19.61}{\pi}\right)}$$

i.e. **diameter of wire = 5.0 mm**

Strain

The fractional change in a dimension of a material produced by a force is called the **strain**. For a tensile or compressive force, strain is the ratio of the change of length to the original length. The symbol used for strain is ε (Greek epsilon). For a material of length ***L*** metres which changes in length by an amount **dl** metres when subjected to stress,

$$\boldsymbol{\varepsilon = \frac{dl}{lo}} \quad \text{and} \quad \boldsymbol{dl = Final\ length - Original\ length}$$

where

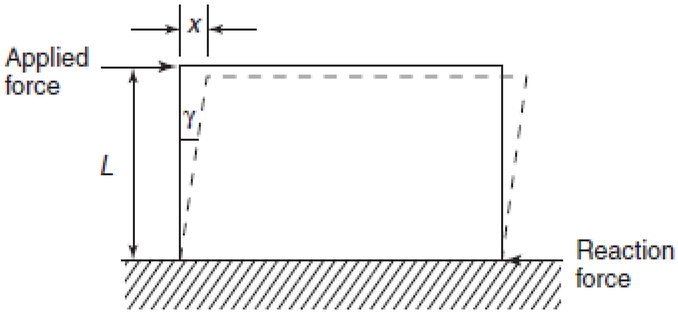
dl = change of length (m)

l_o = initial length (m)

ε = strain - unit-less

Strain is dimension-less and is often expressed as a percentage, i.e.: $\boldsymbol{Percentage\ strain = \frac{dl}{lo} x100}$

For a shear force, **strain** is denoted by the symbol ***γ*** (Greek letter gamma) and, with reference to the following figure, strain is given by: $\boldsymbol{\gamma = \frac{x}{y}}$, Where x is the extension and L is the original length.



Exercise 4.

A bar 1.60 m long contracts axially by 0.1 mm when a compressive load is applied to it. Determine the strain and the percentage strain.

Solution: $\boldsymbol{Strain\ \varepsilon} = \frac{contraction}{original\ length} = \frac{0.1\ mm}{1.60 \times 103\ \text{mm}}$

$$= \frac{0.1}{1600} = \mathbf{0.0000625}$$

Percentage strain = 0.0000625×100 = **0.00625%**

Exercise 5.

A wire of length 2.50 m has a percentage strain of 0.012% when loaded with a tensile force. Determine the extension of the wire.

Solution:

Original length of wire = 2.50 m = 2500 mm

and strain $= \frac{\mathbf{0.012}}{\mathbf{100}} = \mathbf{0.00012}$

Strain $\varepsilon = \frac{\boldsymbol{Extention\ X}}{\boldsymbol{Original\ length\ L}}$

hence, **extension *x*** = εL = *(*0.00012*) X (*2500*)* = **0**.**30 mm**

Exercise 6.

(a) A rectangular metal bar has a width of 10 mm and can support a maximum compressive stress of 20 MPa; determine the minimum breadth of the bar when loaded with a force of 3 kN.

(**b)** If the bar in (a) is 2 m long and decreases in length by 0.25 mm when the force is applied, determine the strain and the percentage strain.

Solution:

(a) Since stress,$\sigma = \frac{Force\ F}{Area\ A},$ then, area,$A = \frac{F}{\sigma} = \frac{3000\ KN}{20 \times 10^6\ \text{Pa}}$

$$= 150 \times 10^{-6}\ \text{m}^2$$

$$= 150\ \text{mm}^2$$

Cross-sectional area = width × breadth, hence

$$\textbf{breadth} = \frac{\text{area}}{\text{width}} = \frac{150}{10} = \mathbf{15\ mm}$$

(b) **Strain,** $\boldsymbol{\varepsilon} = \frac{Contraction}{Original\ Length} = \frac{0.25}{2000} = \mathbf{0.000125}$

$$\text{Percentage strain} = 0.000125 \times 100$$
$$= \mathbf{0.0125\%}$$

Elasticity, limit of proportionality and elastic limit

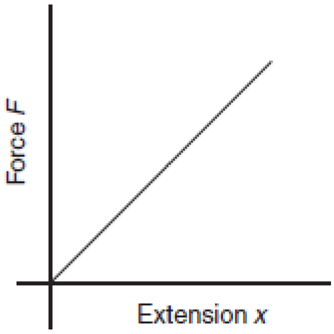
- **Elasticity** is the ability of a material to return to its original shape and size on the removal of external

forces.

- **Plasticity** is the property of a material of being permanently deformed by a force without breaking.

Thus if a material does not return to the original shape, it is said to be **plastic**.
Within certain load limits, mild steel, copper, polythene and rubber are examples of elastic materials; lead and plasticine are examples of plastic materials.

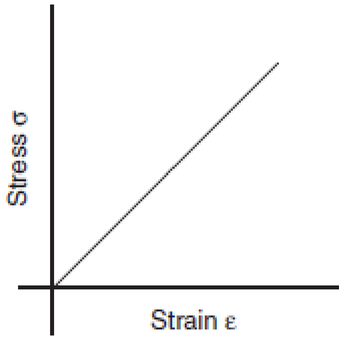
Since the graph is a straight line, **extension is directly proportional to the applied force**, as shown on the following figure.



The point on the graph where extension is no longer proportional to the applied force is known as the **limit of proportionality**. Just beyond this point the material can behave in a non-linear elastic manner, until the **elastic limit** is reached.

If the applied force is large, it is found that the material becomes plastic and no longer returns to its original length when the force is removed. The material is then said to have passed its elastic limit and the resulting graph of force/extension is no longer a straight line.

Hence for stress applied to a material below the limit of proportionality a graph of **stress/strain** will be as shown in the figure bellow, and is a similar shape to the **force/extension**.



<u>Hooke's law</u>

Hooke's law states: Within the limit of proportionality, the extension of a material is proportional to the applied force.

It follows that: Within the limit of proportionality of a material, the strain produced is directly proportional to the stress producing it.

Young's modulus of elasticity
Within the limit of proportionality, stress α strain, hence

stress = (a constant) × strain

This constant of proportionality is called **Young's modulus of elasticity** and is given the symbol *E*. The value of *E* may be determined from the gradient of the straight line portion of the stress/strain graph. The dimensions of *E* are Pascals (the same as for stress, since strain is dimension-less).

$$\boldsymbol{E = \frac{\sigma}{\varepsilon}\ \mathrm{Pa}}$$

Some **typical values** for Young's modulus of elasticity, *E*, include:

- Aluminium alloy 70 GPa (i.e. 70 × 109 Pa)
- Brass :90 GPa
- Copper :96 GPa
- Titanium alloy :110 GPa
- Diamond :1200 GPa
- Mild steel :210 GPa
- Lead :18 GPa
- Tungsten :410 GPa
- Cast iron :110 GPa
- Zinc :85 GPa
- Glass fibre :72 GPa
- Carbon fibre :300 GPa

Ductility, brittleness and malleability

Ductility is the ability of a material to be plastically deformed by elongation, without fracture. This is a property that enables a material to be drawn out into wires.

For ductile materials such as **mild steel, copper and gold**, large extensions can result before fracture occurs with increasing tensile force. Ductile materials usually have a percentage elongation value of about 15% or more.

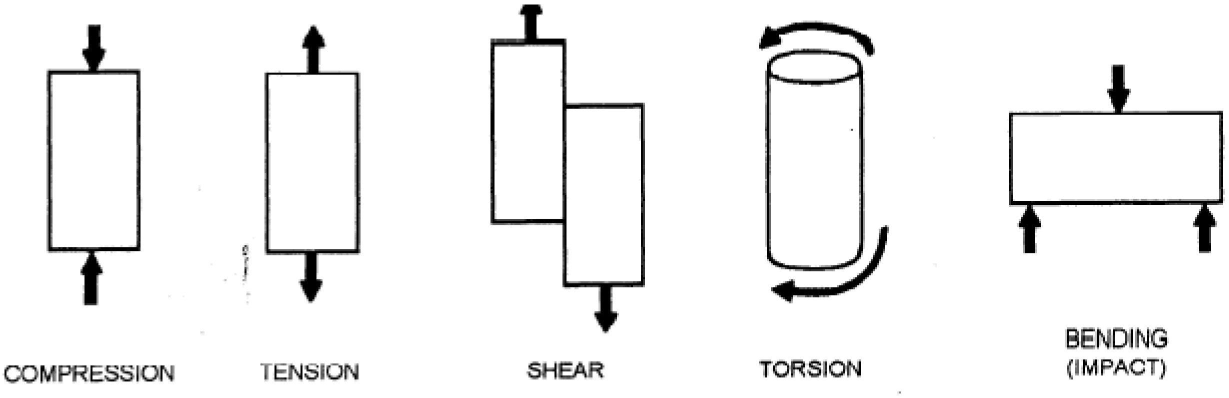
Brittleness is the property of a material manifested by fracture without appreciable prior plastic deformation.

Brittleness is a lack of ductility, and brittle materials such as **cast iron, glass, concrete, brick and ceramics**, have virtually no plastic stage, the elastic stage being followed by immediate fracture. Little or no 'waist' occurs before fracture in a brittle material undergoing a tensile test.

Malleability is the property of a material whereby it can be shaped when cold by hammering or rolling.

A malleable material is capable of undergoing plastic deformation without fracture. Examples of malleable materials include **lead, gold, putty and mild steel**.

Torsion: Torsion testing involves the twisting of a sample along an axis and is a useful test for acquiring information like torsional shear stress, maximum torque, shear modulus, and breaking angle of a material. The following figure illustrates different applications of forces on the materials:



LO 3.3 – Identify Chemical properties

- Content /Topic1: Oxidation

Oxidation: Metal oxidation takes place when an ionic chemical reaction occurs on a metal's surface while oxygen is present. Electrons move from the metal to the oxygen molecules during this process. Negative oxygen ions then generate and enter the metal, leading to the creation of an oxide surface. Oxidation is a form of **metal corrosion.**

(This figure shows corroded bolts and screws after being exposed at fresh air)

When Does Oxidation Occur?
This chemical process can occur either in the air or after the metal is exposed to water or acids. The most common example is the corrosion of **steel**, which is a transformation of the iron molecules on steel's surface into iron oxides, most often Fe_2O_3 and Fe_3O_4.
If you've ever seen an old, rusted car or rusted pieces of metal scraps, you've seen oxidation at work.

Associated reactions

The rusting of iron is an electrochemical process that begins with the transfer of **electrons** from iron to oxygen. The iron is the reducing agent (**gives up electrons**) while the oxygen is the oxidising agent (**gains electrons**). The rate of corrosion is affected by water and accelerated by **electrolytes**.
The key reaction is the reduction of oxygen:
$O_2 + 4\ e^{-} + 2\ H$
$2O \rightarrow 4\ OH-$

Because it forms **hydroxide ions**, this process is strongly affected by the presence of acid. Indeed, the corrosion of most metals by oxygen is accelerated at low **pH.**

Providing the electrons for the above reaction is the oxidation of iron that may be described as follows:
$Fe \rightarrow Fe^{2+} + 2e^{-}$

The following **redox reaction** also occurs in the presence of water and is crucial to the formation of rust:
$4\ Fe^{2+} + O_2 \rightarrow 4Fe^{3+} + 2O^{2-}$

In addition, the following multistep **acid–base reactions** affect the course of rust formation:
$Fe^{2+} + 2\ H_2O \rightleftharpoons Fe(OH)_2 + 2$ **H+**
$Fe^{3+} + 3\ H_2O \rightleftharpoons Fe(OH)_3 + 3$ **H+**
As do the following **dehydration** equilibria:
$Fe(OH)_2 \rightleftharpoons FeO + H_2O$
$Fe(OH)_3 \rightleftharpoons FeO(OH) + H_2O$
$2FeO(OH) \rightleftharpoons Fe_2O3 + H_2O$

Prevention of rusting
Because of the widespread use and importance of iron and steel products, the prevention or slowing of rust is the basis of major economic activities in a number of specialized technologies.

Rust is **permeable** to air and water, therefore the interior metallic iron beneath a rust layer continues to corrode.
Rust prevention thus requires coatings that preclude rust formation like:

1. **Rust-resistant alloys**

Stainless steel forms a **passivation** layer of **chromium(III) oxide.** Similar passivation behavior occurs with **magnesium, titanium, zinc, zinc oxides, aluminium, polyaniline,** and other electroactive conductive polymers.

2. **Galvanization**

Galvanization consists of an application on the object to be protected of a layer of metallic **zinc** by either **hot-dip galvanizing** or **electroplating.** Zinc is traditionally used because it is cheap, adheres well to steel, and provides **cathodic protection** to the steel surface in case of damage of the zinc layer. In more corrosive environments (such as salt water), **cadmium** plating is preferred.

3. **Coatings and painting**

Rust formation can be controlled with coatings, such as **paint, lacquer, varnish,** or wax tapes that isolate the iron from the environment. Large structures with enclosed box sections, such as ships and modern automobiles, often have a wax-based product (technically a "slushing oil") injected into these sections. Such treatments usually also contain rust inhibitors. Covering steel with concrete can provide some protection to steel because of the **alkaline pH** environment at the steel–concrete interface. However, rusting of steel in concrete can still be a problem, as expanding rust can fracture or slowly "explode" concrete from within.

Learning Unit 4 – Identify the area of application of welding materials

LO 4.1 – Identify materials used in Space craft industry

- Content/Topic 1: Types of materials used in space craft industry

Types of materials used in Space craft industry: Should be **Light, Non-corrosive**

- **Light**: replacing cast iron with lightweight materials such as high –strength materials steel, magnesium alloys, aluminum alloys, carbon fiber, and polymer composites can directly reduce weight of space craft materials.
- **Non-corrosive:** different materials resist to corrosion in space differently. For example Aluminium is slowly eroded by atomic oxygen, while gold and platinum are highly corrosion-resistant. Gold-coated foils and thin layer of gold on exposed surfaces are therefore used to protect the space craft from the harsh environment.

What metals are used in spaceships and why?

Answer:

- Space ships need to be solid for safety, but they also need to be light so that they have a better chance of escaping earth's gravitational pull with less fuel or propellant, which is heavy and expensive on its own.

This is why **Aluminum** and **aluminum composite** materials are used on spacecraft. Aluminum is light but also very sturdy. Using titanium alloys can also strengthen the body of the ship.

The space shuttle also had very **special thermal protection tiles**, which helped it survive the heat of re-entry. They are made a ceramic composite, with the bottom of the tiles made from a carbon composite to provide for the most heat protection.

L.O.4.2: Identify materials used in Marine industry

Materials used in Marine industry should be **Non-corrosive.** In today's world, the four main materials used for building boats, when we talk at the level of mass manufacturers, are steel, aluminium, fibre-reinforced plastic (FRP), and polyethylene. Let us speak about each of these in greater detail

1. **Steel**

Steel is one of the most popular materials used for boats and has consistently been the material of choice for the past century. Its high strength, durability, resistance to abrasion, and relatively low cost are some of the main reasons why steel is widely used in the industry. However, in the wake of the development of new composite materials, better and cheaper alternatives are being used for manufacturing boats of equal size and strength but considerably lesser weight. This has reduced the importance of steel in boat building to an extent, although it is still used extensively for larger ships.

2. **Aluminium**

Aluminium is preferred by a lot of boat manufacturers on account of its being lightweight, especially when compared to steel. Aluminium boats are more stable and seaworthy and can travel faster due to reduced weight. This means that you get better mileage for the same quantity of fuel from an aluminium boat. Easy workability and its properties like chemical and corrosion resistance, imperviousness to magnetism, and tendency for plastic deformation make aluminium a strong option for boat building.

3. Fibre-reinforced plastic (FRP)

Fibre-Reinforced Plastic has come to heavily dominate the boat material sector over the past few decades, primarily because it is one of the best options available in the market. A single structure that is light, speedy, strong, watertight, durable, and corrosion-free makes for a great solution. Although initially adopted for military use, FRP has permeated all the levels of maritime applications and is increasingly used as a substitute for wood and steel today.

4. Polyethylene

Polyethylene is an extremely versatile material that serves boat building well across all marine applications like surveillance, amateur and professional fishing, security, etc. The principal quality of high-density polyethylene is that it has a high strength-to-density ratio. Advanced chemical and impact resistance, low maintenance, and greater buoyancy also make it highly suitable for boat construction. Aesthetically, polyethylene boats are moulded (like FRP) as opposed to fabricated (like aluminium). This implies that complex designs are possible, though tolerances for moulding parts are smaller than those for fitting. The processes used to manufacture polyethylene boats include rotational moulding and thermoforming

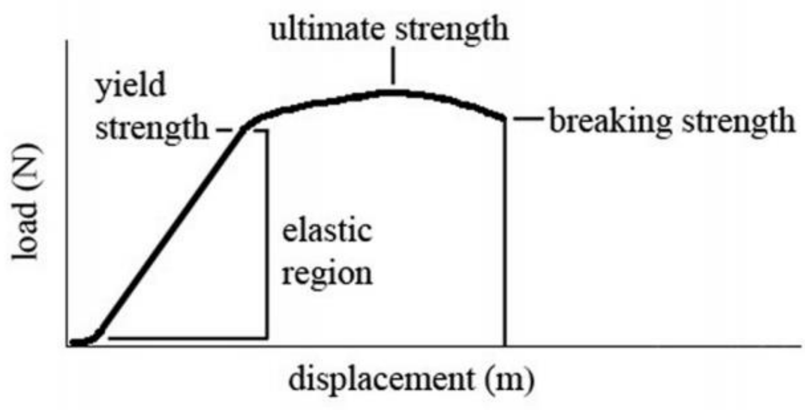
By conclusion

Modern boat and ship design incorporate a variety of hull materials, depending on the size, application, and expected life of the vessel. For smaller, recreational or shallow-sea activities, polyethylene boats are a good choice, both environmentally and economically. FRP boats are preferred for activities like coastal patrol, rescue and security operations, and fishing. Wood, steel, and aluminium remain continuing favorites for larger ships transporting cargo.

Content / topic 2: Material strength.

Here, four-point bending tests were carried out on compact tissue samples of California sea lion (*Zalophus californianus*) limb elements in order to determine the mechanical properties of a previously untested type of semi-marine adapted bone that competed for use in the toolkits of diverse forager groups. Samples of reindeer antler and cervid cortical limb bone served as comparators. To tests determined the stiffness (Young's Modulus), ultimate strength, and fracture resistance of the samples, three measures which relate directly to the performance of skeletal materials as technological ones: how they can be shaped into tools, and how those tools perform under the stresses of use.

Schematic load displacement curve showing key mechanical landmarks. E (material stiffness) is obtained from the slope of the load-displacement curve in the elastic region. The total area under the curve is proportional to the work required to break the specimen.



LO 4.3 – Identify materials used in terrestrial industry

Types of materials used in terrestrial industry are selected according to material **strength** and **density**. Due to the more application of steels in different industry on the earth, the durable, strength, density and lightness of steels have to be calculated and mentioned.

Content / topic 1: Types of materials used in terrestrial industry.

To innate, mechanical properties of tool raw materials place ultimate limits on how the materials can be worked and used, thus affecting most facets of tool use-lives.

A. **Material strength:** The development of materials has always been strongly guided by economic factors. The invention of steel production is undoubtedly the most significant materials technology invention for the modern manufacturing industry. Even though the Chinese knew how to produce steel as early as the third century, it was not until the Bessemer converter, patented in 1855, that the cost of steel manufacture was reduced to the same level as that of cast iron. Steel was a lighter and more durable material, and its extensive use enabled the rapid development of machinery and equipment. Steel grades have continuously been improved since that time; they have been made stronger and more durable for the needs of mechanical engineering.

   The requirements for engineering industry materials have increased continuously with technological development. In the early twentieth century, practically the only requirement for general structural steel grades was related to their yield strength, which could be improved by increasing the carbon content of the steel. Less emphasis was put on toughness, as steel structures were mainly joined together by means of riveting. When welding became more popular, the weldability of steel grades needed to be improved by reducing their carbon content and improving their toughness by controlling the grain size through alloying.

B. **Density:** Density is a material characteristic we all know well. It hides itself within materials though, so we end up not thinking about it very often. We even have jokes about it because of this unintentional veil. "Which weighs more: a ton of feathers or a ton of bricks?" The goal of the "joke" is to trick someone into saying "a ton of bricks" because of course bricks weigh more than feathers! This joke is particularly tricky because it intentionally omits half of the importance of density. Density is defined as mass per unit volume. In our joke setup, we have learned we have an equivalent mass of feathers and bricks. The trick of the joke is the volume. We have no information on the volume of bricks or feathers we have! The mind gravitates to this omission and begins to make assumptions. One has typically held a feather and a brick and will typically make a misguided conclusion to similar volumes of each. Let's be nerds together and see specifically how this joke works. We defined density earlier as the following:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

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