Introduction to engineering materials.

* Classification of engineering materials

The factors that results in classification of engineering materials are :

i> chemical composition of material
ii> Atomic or cystalline structure
iii> Nature of occurence
iv> Industrial and technical use
v> manufacturing process to which it is subjected.

* Types of engineering materials :

i) metals and alloys
ii) ceramics
iii) organic polymers
iv) composite materials
v) semiconductors
vi) biomaterials
vii) advanced materials.

i) Metals :-

a) Pure metals : obtained through refining of ore.
not of use for engineers.

b) Alloyed metals : Alloys are blend of two or more metals or atleast one being a metal. eg 18-8 stainless steel. Properties of alloy may be different from constituent metals.

c) ferrous metals : principal constituent is iron. Depending on % of carbon, these are classified as :

i) Dead-mild steel : upto 0.15 % C, not so hard, ductile, cheap.

ii) mild steel : 0.15 - 0.45 % C, moderately hard, good weldability, low cost.

iii) medium carbon steels : 0.45 - 0.6 % C, high strength, less weldability.

iv) high carbon steels : 0.6 - 1.5 % C, extremely hard, poor weldability.

* Plain carbon steel : upto 1.5% C , upto 1.5% manganese & 0.5% silica.

d) non-ferrous metals : principal element : metal other than ~~fer~~ iron.

e) sintered metals : Those materials whose properties are different from the metals from which they have been cast. ~~Power~~ Power ~~m~~ Powder metallurgy is used. to obtain such metals.

d) clad-metals : A sandwich of two metals is prepared to avail the prop. of both metals, this process is called cladding. eg Cladding of duralium with Aluminium.

* Selection of materials for engineering purpose.

factors affecting selection of materials are :

i) component shape
ii) Dimensional tolerance
iii) availability of material
iv) cost of material
v) cost of processing
vi) fabrication requirements
vii) Service requirements
viii) Mechanical properties.

* Service requirements : corrosion resistance, heat resistance, thermal & electrical conductivity.

* fabrication requirements : weldability, machinability, castability etc.

* method of propessing changes properties of materials.
eg. Forged components are harder than casted components.

* Mechanical properties of metals

These are the properties which are associated with ability of metal to resist mechanical forces or load. eg. strength, stiffness, elasticity, plasticity etc.

* WROUGHT IRON

Purest form of iron (99.5–99.9%).

% C = 0.020 & % S = 0.12 & % Slag = 0.070 & % P = 0.020 & % S = 0.018.

It is produced from pig-iron by re-melting it in puddling furnace of reverberatory type. Tensile strength = 250–500 MPa & compressive strength 300 MPa. Tough, malleable, ductile. applications in crain hooks, chains, pipes etc.

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* STEEL: Alloy of iron and carbon. Carbon % upto 1.5 %.

Plain carbon steel, dead-mild, mild, high carbon steel have been discussed earlier.

* Effect of impurities on Steel:

i) Silicon: 0.05–0.30 %. prevents from becoming porous. removes gases & oxides and toughens the steel.

ii) Sulphur: exist in mag. sulphide & iron-sulphide form (harmful). produces red shortness. (breaking red hot temp.).

iii) Maganese: Powerful purifying and de-oxidising Agent. good ductility and toughen metal & increase critical temp.

iv) Phosphorus: produces cold shortness., makes it brittle (<0.25%).

* Free cutting steels: contain sulphur and phosphorus.
0.1 – 0.45 % S and 0.08 – 0.3 % S.
used where rapid machining is required.
Lead can be used in place of sulphur (0.05–0.2%).

* Alloy steel:

i) Nickel: 2-5 % Nickel, 0.1 – 0.5 % C. ↑ strength and toughness.
good ductility and corrosion resistance.
25 % nickel alloy steel possess max. strength & corrosion-resistant prop.
36 % nickel alloy is called invar.
used in valves for superheated steam & valves for IC engines, for measuring instruments.

ii) Chromium: 0.5–2 % Cr and 0.1–1.5 % C. ↑ strength and hardness & elastic limit. used for balls, rollers for bearings.
Nickel chrome steel containing 3.25 Ni, 1.5 % Cr & 0.25 C is used for armour plates. It is used for pipes, axels & gears.

iii) Tungsten: retains hardness even at red hot temp.
3–18 % tungsten and 0.2–1.5 % C.
used for cutting tools, permanent magnet.

iv) vanadium : ↑ tensile strength, ductility and elastic limit.
(added less than 0.2 %).
applications in shafts and gears.

v) manganese : over 1.5 % manganese & 0.40 – 0.55 % C.
improves strength of steel at high temp.
used in gears, axels, shafts etc.

vi) silicon : similar behaviour to nickel. 1-2 % silicon & 0.1 – 0.4 % C.
uses : valves in IC and springs.

vii) cobalt : increases red hardness due to retention of carbide. ↑ magnetic properties, hardness & strength.

viii) malybednum : (0.15 % – 0.30 %) molybednum with Cr & Mn.
extra tensile strength, used in automobile parts.

* Stainless steel : correctly heat treated, avoid corrosion and oxidation from corrosive media.

i) martensitic stainless steel : magnetic steels, get hardned at high temp, 12 – 14 % chromium and 0.12 to 0.35 % C. Tensile strength 600-900 MPa. applications in oil and steam pumps and valves.

ii) Ferritic stainless steel : 16–18 % Chromium & upto 0.12 % C.
does not get hardened by heat treatment. better corrosion resistance property than martensitic steel.

when 1.5–2.5 % Ni added to 16-18 % chromium steel, the resultant steel gets hardened by heat treatment. better corrosion resistance than martensitic steel. used in pump-shafts, spindles & valves.

iii) Austenitic stainless steel :
18-8 Nickel-chromium steel. C content as low as posible.
Not hardened by quenching ; non-magnetic ; greatest corroision resistance.
easily welded but corrosion-property weakens after this, so it is softened to get that property back.

used in screws, nut, bolts, pump shafts etc.

* 2-3 % mo ~~b~~ may be added.

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* HEAT - resisting steels: resists creep and oxidation at high temperature and retain sufficient strength.

i) low alloy steels: upto 0.5 % Molybednum. Service temp: 400-500°C applications in super heated tubes and pipes.

ii) valve steels: eg. Silchrome ((0.5%-0.1)% C, 8% chromium, 3.5% Si), & volmax (0.5% C, 8% Cr, 3.5% Si, 0.5 Mo) are used for automobile parts. good resistance at dull red heat.
eg 13/13/13 nickel-co, tungsten.
apps in marine diesel engines & aeroplane engine valves.

iii) Plain Chromium steels :- i) Martensitic (750° ST) ii) Ferritic. (1000-1150°C).

iv) Austenitic Cr-Ni steels: use upto 1000°C.
good resistance. 18-8 Ni-Cr steel.

* High speed Tool Steels :- use for cutting metals at much higher speed than ordinary C tool steels.
retains their sharp edges at high temperatures.

i) 18-4-1 high speed steel: 18% tungsten, 4% Cr, 1% vanadium.
applications in drills, planer & shaper tools, punches.

ii) Molybednum high speed steel: 6% Tungsten, 6% Mo, 4% Cr & 2% V.
better and cheaper. excellent toughness & cutting ability.
app. in drilling & Tapping.

iii) Super-high speed steel. (Co). 2-15% Co. ↑ cutting efficiency.

* SPRING STEELS.: most suitable material for springs is that it should possess high elastic limit, without permanent deformation for aeroplane purpose, max. strength against fatigue & shock is required.

i) High carbon steels: 0.6-1.1% C, 0.2-0.5 Si, 0.6-1% Manganese.
hardened by quenching at temp. 780-850°C and tempered at 200-500°C.
used in Locomotives, wagons & for heavy road vehicles.

ii) Chrome-vanadium: 0.45 - 0.55 % C, 0.9-1.2 % Si, Cr, 0.15 to 0.20 V, 0.3-0.5 Si, 0.5 to 0.8 Mn.

have high elastic limit.
hardened by quenching at 850°-870°C. & tempered at 470-510°C.
applications in aircraft engine valve springs, coil springs.

3) Silicon-Manganese : 1.8-2% Si, 0.5-0.6% C, 0.8-1% Mn.
high fatigue resistance, toughness and elastic limit.
quenching at 850-900°C & tempered at 475-525°C.
apps in modern spring materials.

* Heat Treatment of Steels.

i) To increase hardness / softness / improve machinability / ↑ electrical & mag. properties.

* Cast-Iron : obtained by re-melting pig iron with coke & lime-stone in cupola furnace. 1.7-4.5% C content.
Carbon exists in two forms (i) graphite ii) combined.
It is brittle, so it should not be used for making components subjected to shocks.

* Advantages : low-cost, good casting properties, compressive strength & good machinability.

* Tensile strength = 100 to 200 MPa.

* compressive strength = 400-1000 MPa.

* shear strength = 120 MPa.

* TYPES OF CAST-IRON :

i) Grey cast-iron :

3-3.5% C ; Si : 1 to 2.75% ; Mn : 0.4 to 1% ; Phosphorus = 0.15 to 0.1
Sulphur : 0.02 to 0.15%

* no ductility, less tensile strength, high compressive strength. Grey in colour due to presence of graphite form of Carbon. can be used in that part where sliding action is required.
applications in pipe fittings and agricultural implements.

ii) White cast-iron :

1.75-2.3% C ; Si - 0.85 to 1.2% Mn : <0.4% ; Ph : <0.2% ; S : <.12%

white colour is due to combined form of carbon (carbide).
compressive strength >> tensile strength. hard. cannot be machined.
app : rollers for crushing grains.

* Malleable cast-iron : combined form of carbon. (ductile)
may bent without breaking. tensile strength > that of grey cast iron.
excellent machining qualities.
Apps : locks, pipe fittings etc.

* Alloy cast iron :
what we have studied so far is called plain cast iron. When alloying elements are added to plain cast iron, it is called alloy cast-iron. ↑ strength, corrosion resistance and wear resistance.
Applications in pistons, break shoes, gears etc.

* Effect of impurities on cast-iron.
i) Silicon : < 0.4 %. provides formation of free graphite & easily machinable.
ii) Man Sulphur : < 0.71 %. makes hard and brittle.
iii) manganese : < 0.75 %. makes white and hard.
iv) Phosphorus : < 1 %. brittleness ↑.

* NON-ferrous Metals.
They have following characteristics :

i) Ease of fabrication
ii) Light weight
iii) Resistance to corrosion.
iv) Electrical and thermal conductivity.

* Aluminium
produced from alumina which is ppd. from bauxite.
specific gravity 2.7 and 658°C melting point.
Tensile strength 90 – 150 MPa.
Good electrical conductivity.
Good corrosion resistance and non-toxicity.
Apps : utensils, wrapping foil.
light weight : in aeroplane components.

* Aluminium alloys.
Duralium : 3.5–4.5 % copper & 0.4 to 0.7 : Mn & Mg
Tensile strength (400 MPa)
Service temp : 500°C
high strength & light weight : aircraft components, rods, pulley etc.

* Copper : Soft, malleable, ductile. (reddish - brown).
specific gravity = 8.9 & 1083°C melting point.
Tensile strength = 150 - 400 MPa. and good conductor of electricity.
Applications : electrical cable and wires, electroplating.

* Brass : Alloy of Copper and zinc
addition of lead 1-2 % improves machinability.
greater strength than copper but less thermal & electrical conductivity.

* Bronze : Alloy of copper & tin.
(75-95) % (5-25) %
comparitively hard, resistance to surface wear, malleable & ductile.
Corrosion resistance properties > that of brass.

* SUPER ALLOYS

A super alloy, or high-performance alloy, is an alloy that exhibits several key characteristics :
excellent mechanical properties, corrosion resistance, good surface stability etc
The crystal lattice is typically face-centred cubic.

Super alloy is a metallic alloy with high mechanical strength and resistance to surface degradation at high temp (650°C).

Oxidation and corrosion resistance is provided by formation of oxide layer which is formed when metal is exposed to air.

Majorly, 3 classes of super alloys are :

i) Nickel based super alloys
ii) Cobalt based super alloys
iii) Iron based super alloys.

eg : Hostelloy, incoloy etc.

Applications : Aircraft gas turbines, pollution control equipment, coal gasification, nuclear power system, chemical industries.
$\underbrace{\text{chemical industries}}_{\text{fans, piping pumps.}}$

* Ceramics

Ceramics are the inorganic material consisting of metals, non-metals & semi-metals. eg. glass, cement, concrete, silica etc.

Applications in computer memories, artificial bones and teeths.

* Mechanical properties of ceramics :

i) rigid and brittle

ii) strength of ceramics is higher than that of metals.

iii) Bonding in ceramics is more rigid.

iv) Tensile strength and toughness are relatively low.

* Physical properties :

i) Ceramics are lighter than corresponding constituent metal.

ii) Melting pt. of ceramic is higher than that of metal.

iii) Electrical and thermal conductivity are lower of most ceramics.

* Composite materials.

They are made to avail the advantages of diff. properties of organic polymer, metals and ceramics. These are manufactured by combination of two or more materials. In composite material, there is a matrix matrix and reinforcing material. They are classified on basis of matrix matrix and orientation of fibre.

i) PMC : polymer matrix composite

When organic polymer like epoxy is used as matrix material. The composite is called PMC. eg: glass fibre reinforce plastic & carbon fibre reinforce plastic (GFRP & CFRP)

ii) CMC : Ceramic matrix composite.

It consists of ceramic fibre embeded in ceramic matrix.
SiC embeded with Fibre.

iii) MMC : Metal matrix ~~ceramic~~ composite (MMC).

In this, there is a matrix of any ductile material like Mg & Ti, mixed with silicon carbide, Boron carbide, alumina etc.