



**GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY**

Department of Mechanical Engineering

## **Workshop Technology**

ME 1103

## **CONTENT**

### **1. Engineering Materials**

- a. Classification of metals
- b. Ferrous metals, Non-ferrous and alloys
- c. Production of iron & Steel
- d. Non-metals
- e. General characteristics and mechanical properties of metal & uses

### **2. Engineering Measurements**

- a. Units & standards
- b. Measurements of physical parameters
- c. Types of measuring instruments – Steel rule, Veneer caliper, Micrometer, Bore gauge, Height gauges & Depth Gauges, Calipers

3

### **3. Workshop machines & tools**

- a. Introduction to workshop tools
- b. Hand tools & Power Tools

### **4. Workshop Safety**

- a. Selection of tools
- b. Factors Contributing to Accident
- c. Common Causes of Injuries
- d. Basic Rules to Prevent Injuries
- e. Basic fire extinguishing

4

### **5. Lathe machines**

- a. Introduction
- b. Function of lathe
- c. Types of lathe
- d. Descriptions & functions of lathe parts
- e. Lathe accessories & attachments
- f. Feed mechanism
- g. Thread cutting mechanism
- h. Lathe operations: turning, facing, knurling

5

### **6. Metal Casting**

- a. Metal melting
- b. Expandable, Permanent & Composite molds
- c. Sand casting
- d. Shell Molding
- e. Expendable pattern casting
- f. Plaster and Ceramic Mold Casting
- g. Investment casting
- h. Vacuum casting
- i. Permanent mold casting
- j. Die casting & centrifugal casting
- k. Defects in casting and prevention of defects

6

### **7. Metal Forming and Shaping**

- a. Introduction
- b. Yielding and plastic flow
- c. Classification of forming processes
- d. Blanking and bending
- e. Drawing, Extrusion, Stamping, Embossing etc

7

## 8. Metal Joining

- a. Introduction to Joining processes
- b. Fusion Welding processes
  - i. Classification of fusion welding processes
  - ii. Oxy-fuel gas welding, Flame types and applications
  - iii. Arc Welding, Arc welding principle and processes
  - iv. SMAW, SAW, GMAW, GTAW, FCAW
- c. AWS classification system for electrodes and selection
- d. Mechanical fastening
- e. Adhesive bonding
- f. Brazing and soldering
- g. The hazards and types of PPE

8

## Practical

1. Bolt machining – Lathe machine
2. Arc Welding
3. Gas Welding

9

## Learners should be able to:

- Explain basic engineering materials and their properties
- Apply the features and operational principle of machining processes and use different workshop machinery
- Select suitable machining and fabrication processes for producing simple mechanical products
- Machine simple components or devices with available facilities at the engineering workshop

10

- |                     |             |
|---------------------|-------------|
| + Practical         | - 30% marks |
| + Semester End Exam | - 70% marks |

**= YOUR RESULT**

11

## References

- Chapman, W.A.J (1997). Workshop Technology, part 1,2,3, Viva Books Private Limited
- Bolton, W. (1990). Production Technology; Process Material Planning, Tata McGraw – Hill Co.
- James Anderson, Earl E. Tatro (1992). Shop Theory, Tata McGraw – Hill Co.

12



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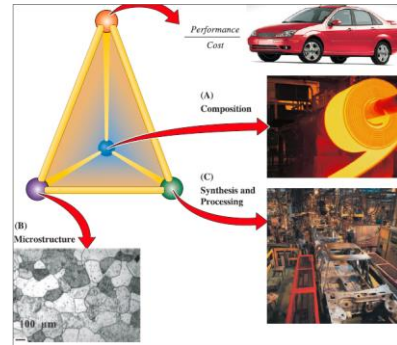
## Fundamentals of Manufacturing

### 1. Engineering Materials

Car: ~ 15,000 parts;  
Boeing 747 plane: ~ 6 million parts  
Intel core 2 duo processor: 65 nm  
feature size, 291 million transistors

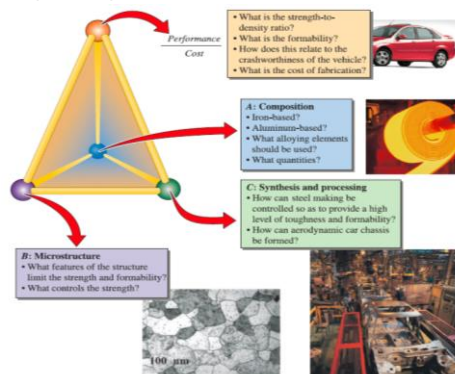
15

### Engineering Material Tetrahedron



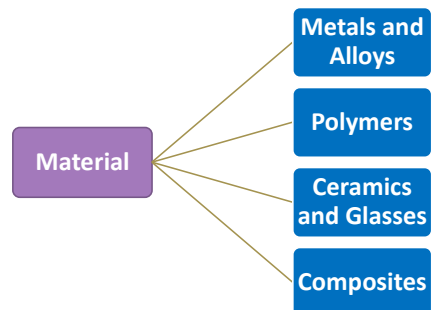
17

### Engineering Material Tetrahedron for Sheet Steel



18

### General Material Classification



19

### Classification of Materials

#### Metals

- good conductors of electricity and heat
- lustrous appearance
- susceptible to corrosion
- strong, but deformable



#### Ceramics & Glasses

- thermally and electrically insulators
- resistant to high temperatures and harsh environments
- hard, but brittle



#### Polymers

- very large molecules
- low density, low weight
- maybe extremely flexible



#### Composites

- consist of more than one material type
- designed to display a combination of properties of each component

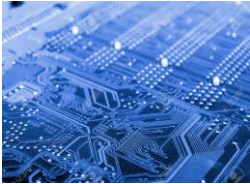


21

## Classification of Materials : Few additional Categories

### Semiconductors

- electrical properties between conductors and insulators
- electrical properties can be precisely controlled



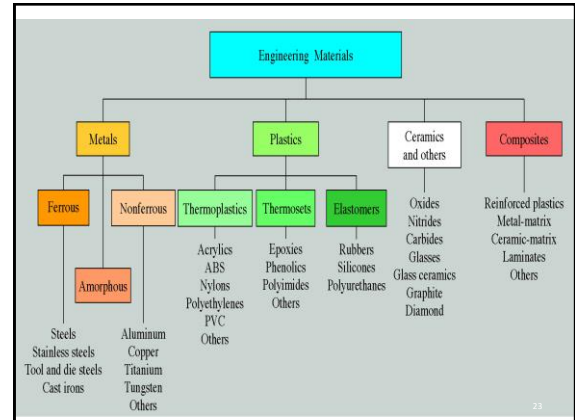
### Biomaterials

- implanted in human body
- compatible with body tissues

hip replacement



22



23

## General Material Classification

### 1. Metals

- Ferrous metals and alloys
  - Iron, Carbon Steels, Alloy Steels, Stainless Steels, Tool and Die Steels
- Nonferrous metals and alloys
  - Aluminum, Copper, Magnesium, Nickel, Titanium, Brass, Bronze, Super alloys

24

### • Pure metals

- Elements which comes from the particular area of the periodic table
- Ex: Fe, Cu, Au, Al , etc.

25

### • Alloys

- Metal alloys contain more than one element.
- Different properties can be obtained by changing the elements present in the alloy.
- Ex: Cu+Zn (Brass), Cu+Sn (Bronze)
- Supper Alloys consists more than 10-15 Elements

26

### 2. Polymers

#### Types of polymers

- Natural polymers
  - Rubber, Starch (softer)
  - Cellulose, Protein (Harder)
- Synthetic polymers (Plastics)
  - Polyethylene, PTFE (Poly Tetra Fluoro Ethylene) , SBS (Styrene Butadiene Styrene) Rubber, ABS (Acrylonitrile Butadiene Styrene) - (easy to deform)
  - PVC, Nylon, Polystyrene Silicon (Hard, Tough)

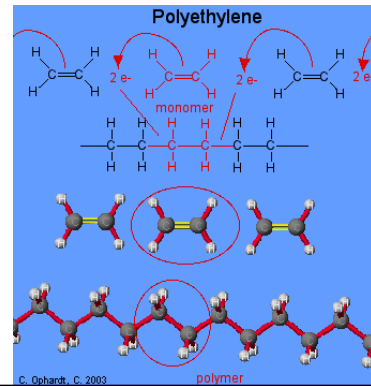
27

### Polymers,

- Has repeating structure, usually based on carbon backbone.
- The repeating structure results in large chain like molecules.
- Usually light weight, corrosion resistance, can easily processed at low temperature & inexpensive.
- Generally strength improved using reinforced composite structures.
- Poor in conducting of electricity & heat, and thereby becomes good insulators.

28

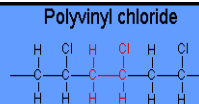
### • Poly Ethylene / Polythene (PE)



29

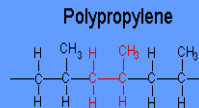
### • PVC (Poly Vinyl Chloride)

- Pipes



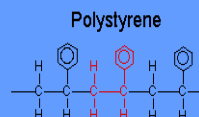
### • Poly Propylene (PP)

- Bottles, Craters



### • Poly Styrene (PS)

- Regiform



C. Ophardt, C. 2003

30

### • Poly Methyl Meth Acrylate (PMMA)

- Perspex  
(Transparent, Light weight)



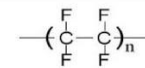
This is poly(methyl acrylate).  
It is soft and rubbery.



This is poly(methyl methacrylate).  
It is a hard plastic.

### • Poly Tetra Fluoro Ethylene (PTFE)

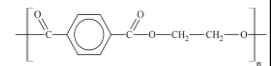
- Thread seal, non stick pans



Polytetrafluoroethylene repeat unit. The degree of polymerization, n, is often very high (>1000).

### • Poly Ethylene Terephthalate (PET)

- Mineral water bottles



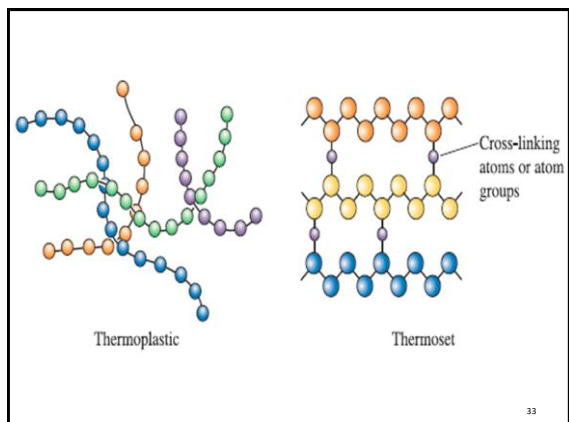
31

## Classification of Polymers

### Thermoplastics

Reversible in phase by heating and cooling. Solid phase at room temperature and liquid phase at elevated temperature. In which the long molecular chains are not rigidly connected, have good ductility and formability. Thermoplastics are made by shaping their molten form.

32



33

### Thermosets

Irreversible in phase by heating and cooling. Change to liquid phase when heated, then follow with an irreversible exothermic chemical reaction. Remain in solid phase subsequently. They are stronger but more brittle because the molecular chains are tightly linked. Thermosets are typically cast into molds.

34

### Elastomers

High elasticity which gained from the arrangement of the polymer chains (spiral like forms). Chains are not chemically linked together may cause permanent deformation at higher load. This come by lightly cross linking before use (natural rubber – by adding sulphur to compound and heating it under high pressure, known as vulcanization.)

35



36

### 3. Ceramics

- Ceramics broadly defined as any inorganic nonmetallic material
- High melting temperature
- Low density
- High Strength, Stiffness, Hardness, Wear resistance & corrosion resistance
- Insulator
- Very brittle

38

### Types of Ceramics

- ❖ Natural ceramics (Traditional ceramics)
  - Beach sand
  - Rocks
  - Clays

39

Traditional ceramics are used to make

- Bricks
- Tableware
- Tiles
- Bathroom Sinks
- Refractories
- Abrasives



40

### ❖ Advanced ceramics

Advanced ceramics are materials made by refining naturally occurring ceramics and other special processes. It includes;

- oxide ceramics : alumina
- carbides : silicon carbide, titanium carbide, etc.
- nitrides : silicon nitride, boron nitride, etc.

41

Advanced ceramics are used to make

Computer Chips  
Sensors and Actuators  
Capacitors  
Wireless Communications  
Spark Plugs  
Inductors  
Electrical insulations



### • Glass

Inorganic non metallic material that doesn't have Crystalline (atoms & molecules are arranged in an order) structure. Those are called Amorphous materials.

- Window glass
- Containers (soda lime silicate)
- Light bulb glass
- Laboratory glass
- Fiber glass
- Optical glass
- Optical cables (purity silica glass)

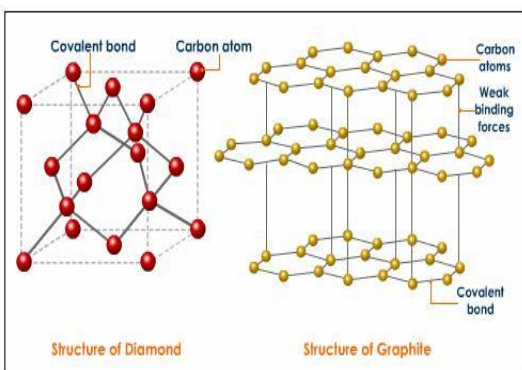
44

### • Diamond and Graphite

The property of an element to exist in two or more physical forms in the same physical state by having similar chemical composition, with different physical properties is called allotropy.



45



46

## 4. Composites

- Formed from two or more materials.
- In order to obtain Superior properties than individual material or component.



49

### Some of important composites

- Particulate
  - Concrete
  - Asphalt mix
  - Chip boards
- Laminate
  - Cladded mat – Ni Cladded Al alloy
  - Plywood
- Fiber Reinforced
  - GFRP
  - Asbestos
  - Fiber boards

50

### Fibres

- Function is to carry the load along the direction of the load being applied.
- Hence, they are often align in the direction of loading. Externally applied forces are transferred to it and distributed among the fibers.
- Generally fibers are
  - High in strength
  - High in modulus of elasticity
  - Chemically inert

51

### Matrix

- Provides toughness to the composite.
- Also binds the fibers together and protects them from corrosive environments.
- Polymers are widely used
- Has the ability to,
  - bond fibers and protect them from surface damage
  - transfer the load to the fiber without damage
  - counteract the brittle behavior of the fiber
  - form a strong matrix-fiber interface

52

### • Metal Matrix Composites (MMC)

- Mixture of ceramics and metals reinforced by strong, high-stiffness fibers

### • Ceramic Matrix Composites (CMC)

- Ceramics such as aluminum oxide and silicon carbide embedded with fibers for improved properties, especially high temperature applications.

### • Polymer Matrix Composites (PMC)

- Thermosets or thermoplastics mixed with fiber reinforcement or powder.
- GFRP (Glass Fiber reinforced Plastic)

53

### Properties of Materials

1. Mechanical properties of materials
  - Strength, Toughness, Hardness, Ductility, Elasticity, Fatigue and Creep
2. Physical properties
  - Density, Specific heat, Melting and boiling point, Thermal expansion and conductivity, Electrical and magnetic properties, Opaque or Transparent
3. Chemical properties
  - Oxidation, Corrosion, Flammability, Toxicity
4. Environmental
  - Green, Recycling

55

### Material Specification

Under various conditions (temperature, humidity, pressure) and using above properties materials can be specify.

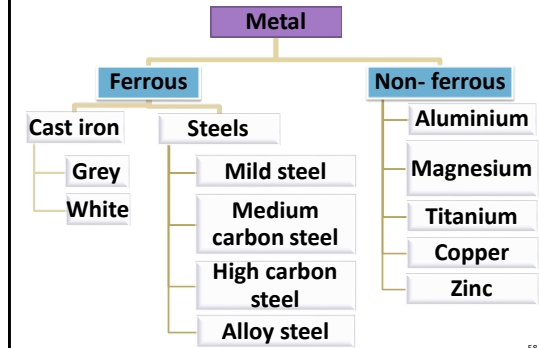
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## Metals

- Metal has properties that satisfy a wide variety of design requirement.
  - ✓ High strength & Stiffness (not flexible)
  - ✓ Good ductility (easy to deform)
  - ✓ Higher Toughness
  - ✓ Good electrical conductivity
  - ✓ Good thermal conductivity
  - ✓ Some have magnetic properties (Fe, Co, Ni)
- Manufacturing methods are available which they are shaped into products.
- Cost is low with other Engineering materials.

57

## Classification of Metal



58

## 1. Ferrous Metal

- Ferrous metal include all forms of Iron & Ferrous alloys.
- Ferrous alloys are useful metals in terms of mechanical, physical and chemical properties.
- Alloys contain iron as their base metal.
- Carbon steels are least expensive of all metals while stainless steels is costly.

59

- Ferrous metals are magnetic.
- Main Iron Ores,
  - ✓ Magnetite ( $\text{Fe}_3\text{O}_4$ )
  - ✓ Hematite ( $\text{Fe}_2\text{O}_3$ )
  - ✓ Limonite ( $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ )
  - ✓ Siderite ( $\text{FeCO}_3$ )

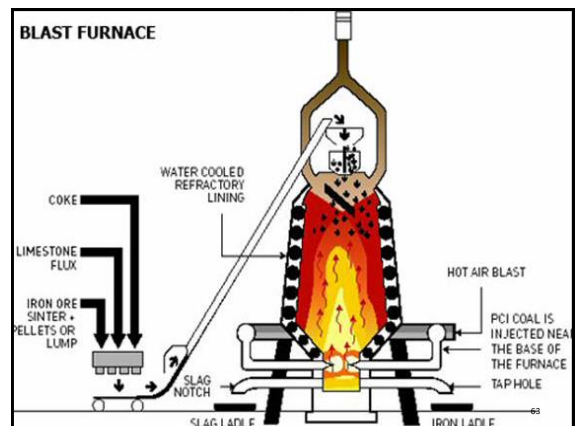
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- Iron Ores are refined to remove Impurities (C,  $\text{O}_2$ ,  $\text{H}_2\text{O}$ ).

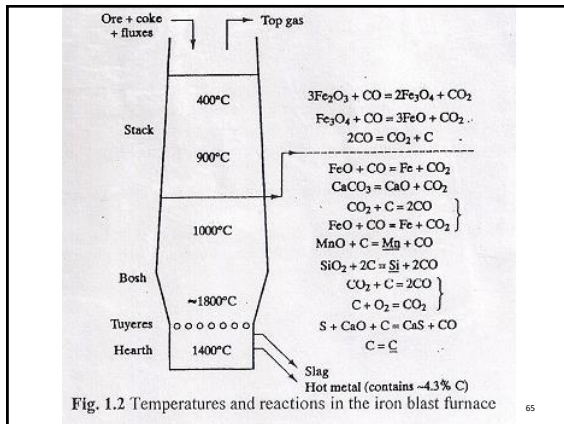


- Pig iron is obtain from the iron ores by smelting in a Blast Furnace.
- Reducing agents are Charcoal or Coke & Limestone or Dolomite is used as a flux to enhance slag formation.

61



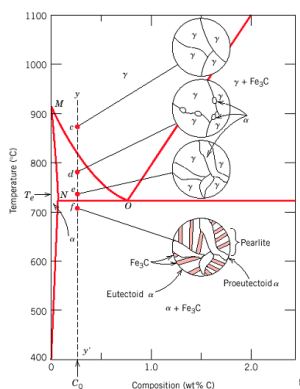
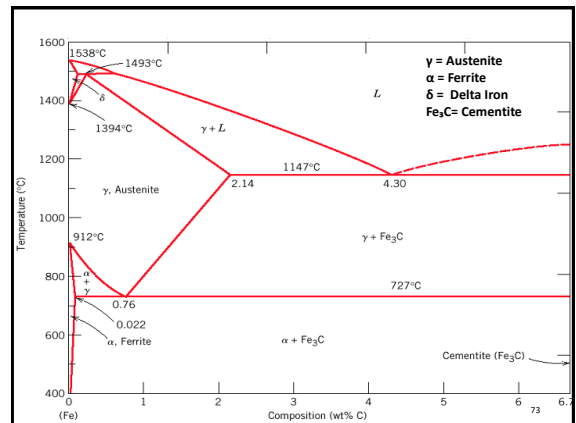
62



## Blast furnace

- The purpose of a blast furnace is to chemically reduce and physically convert iron oxides into liquid iron called "hot metal".
- The blast furnace is a huge, steel stack lined with refractory brick, where iron ore, coke and limestone are dumped into the top, and preheated air is blown into the bottom.
- The raw materials require 6 to 8 hours to descend to the bottom of the furnace where they become the final product of liquid slag and liquid iron.

- These liquid products are drained from the furnace at regular intervals. The hot air that was blown into the bottom of the furnace ascends to the top in 6 to 8 seconds after going through numerous chemical reactions.
- Once a blast furnace is started it will continuously run for four to ten years with only short stops to perform planned maintenance.



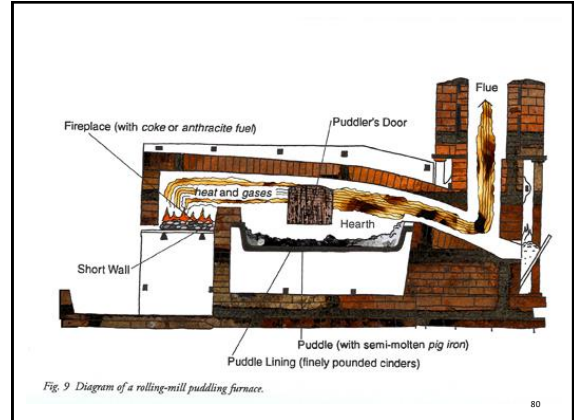
## Pig Iron

- Contain 93% iron, Carbon 4%-6% & various other elements.
- Obtained from the ore by smelting in a blast furnace.
- Weak & Brittle due to high carbon content.
- Wrought iron, Steel & Cast iron produced using Pig iron. (90% of pig iron)
- Used for pipe lines, some fittings and valves.

## Wrought Iron

- Carbon (0.01%) is eliminated as the form of carbon monoxide.
- Wrought iron is soft, malleable & ductile.
- It can be welded (Gas, Arc), machined & easily formed.
- Has low hardness & low fatigue strength.
- Used to make rivets, bolts, chains, water and steam pipes & ornamental iron works.
- Puddling furnace is used to produce wrought iron.
- Presently not considered as pure iron because current standards for commercially pure iron is  $C\% < 0.008$  wt%.

79



80

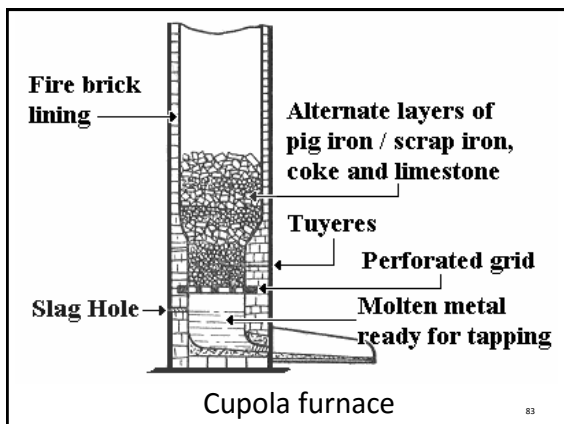


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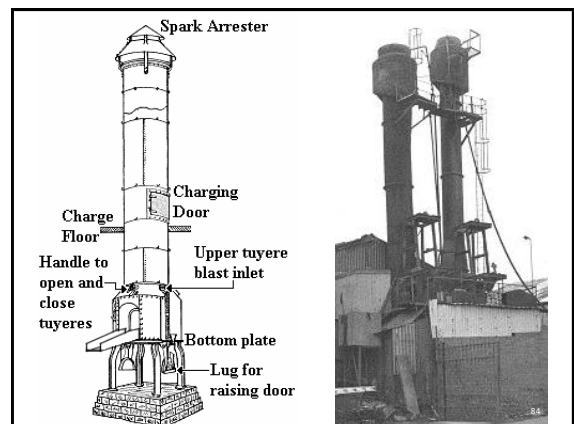
## Cast Iron

- Contain typically 2-4% wt Carbon, high Silicon percentage & greater concentration of impurities than steels.
- Cupola furnace is used to produce cast iron.
- High compressive strength & wear resistance.
- Lack ductility, malleability & impact strength.
- Alloying with nickel, chromium to improve toughness, hardness & tensile strength.
- Produce by re-melting charges consisting of pig iron, steel scrap, cast iron scrap in a cupola furnace.

82



83



84

### Advantages of using cast iron

- Can be sand cast to complex shapes using basic technology
- Can be melted easily
- Clean surface
- Range of Strength & Hardness

86

### Disadvantage

Brittle, cannot be used for high stress

- Low impact properties
- Two types
  - ✓ Gray Cast iron (C – 1.8 - 3.6 %)
  - ✓ White Cast iron (C – 2.5 – 4 .0%)

87

### Gray Cast iron (C – 1.8 - 3.6 %)

#### Properties

- Oldest and most common
- Produced at slow cooling
- High compressive strength
- Fatigue resistance
- Excellent machinability
- Self-lubricating properties
- Weak in tension
- Wear resistance
- Good vibration damping

88

### Gray Cast iron

#### Applications



Crank shaft



Machine parts

89



Drain cover



Engine Block

90



91



Automobile parts, machine parts, pump parts, gear box castings, motorcycle parts, couplings, flanges, fittings, pulleys, engine exhaust manifolds, burners, grates, grills, plates.

### White Cast iron (C – 2.5 – 4.0%)

- More Iron carbide ( $\text{Fe}_3\text{C}$ )
- Very hard & High wear resistance
- Un-machineability
- Very brittle

Adding Chromium, increase hardness and improve abrasion resistance.

Cr 10% used for railway-car wheels, crushing rolls, stamp shoes and dies & many heavy-duty machinery parts.

93

## Steel

### Carbon Steel & Alloy Steel

- *Carbon Steel* – Steel - ( $\text{Fe} + \text{C} + \text{Mn}$ )  
< 0.5% Manganese & 0.5% Silicon.
- All other Steels – *Alloy Steels*  
( $\text{Fe} + \text{C} + \text{Mn} + \text{other additions}$ )

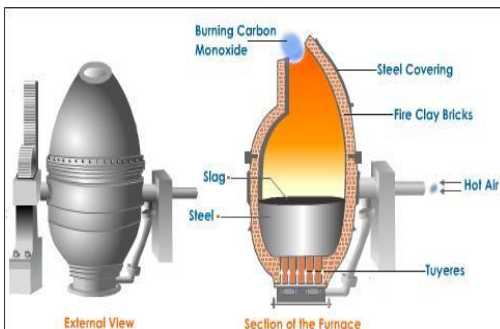
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## Carbon Steel

- Group which contain Carbon percentage 0.008 up to 2.14%.
- Use Bessemer converter, open hearth furnace, Electric arc furnace, induction furnace, Oxygen steel making process to produce steel.
- Can be formed into shapes by plastic deformation (Rolling, Forging)
- Can be treated to give them a wide range of mechanical properties.

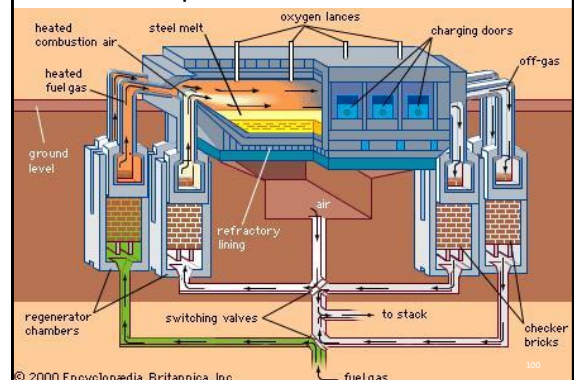
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## Bessemer converter



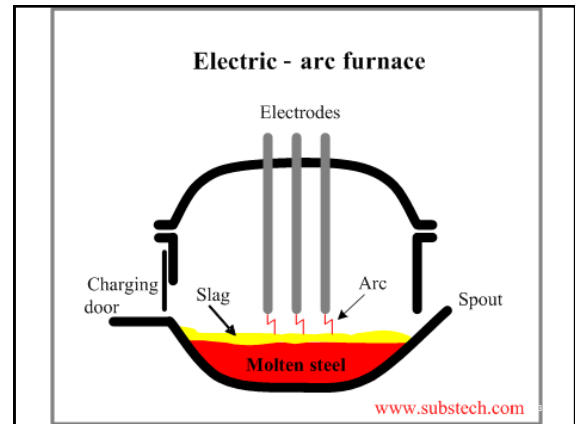
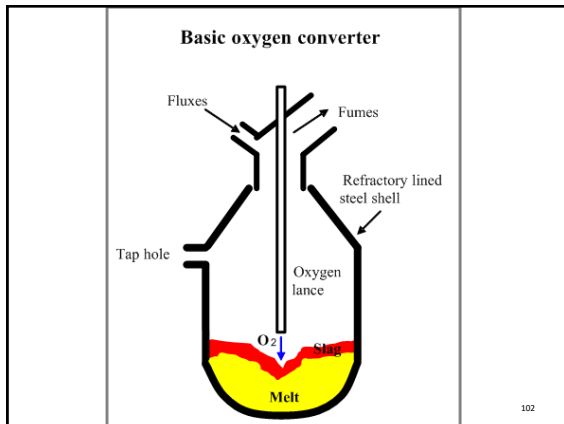
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## Open hearth furnace



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99



- **Machinability** – Ability to remove material. For that metal need to have some kind of hardness as well
- **Hardenability** – ability to harden by heat treating

1. **Carbon steels** - Classified as low, medium and high:

**Low-carbon steel or mild steel, < 0.3%C**

- Good formability and weldability, low strength, low cost
- 55-60% machinability
- Deep drawing parts, chain, pipe, wire, nails, some machine parts
- Lack of hardenability due to low C content

**Medium-carbon steel, 0.3% ~ 0.55%C.**

- Good toughness and ductility, relatively good strength, may be hardened by quenching
- Fair formability
- 60-70% machinability
- Rolls, axles, screws, cylinders, crankshafts, heat treated machine parts

**High-carbon steel, 0.55% ~ 0.8%C.**

- High strength, hardness and wear resistance, moderate ductility
- Higher hardenability
- Rolling mills, rope wire, screw drivers, hammers, wrenches, band saws

**Tool carbon steel, C > 0.8%. – subgroup of high carbon steels**

- very high strength, hardness and wear resistance, poor weldability, low ductility
- punches, shear blades, springs, milling cutters, knives, razors

- Carbon Steel is obtained by refining pig iron
- The Bessemer converter, open hearth furnace, electric arc furnace can be used to produce steel.
- Steel can be cast but technically difficult (due to high melting temperature & high cost)

108

## Carbon Steel

### Advantages

- Low cost
- High strength
- Relatively high Toughness
- Can be Weld

### Disadvantages

- Heavy (high density)
- Poor Corrosion resistance

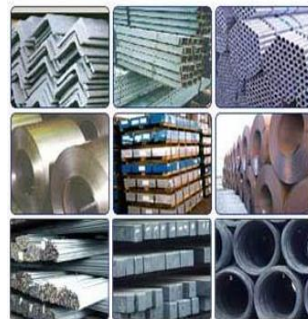
109

## Steel bridges & structures



110

## Furniture and other applications



111

## 2. Alloy Steels - Steels containing significant amounts of alloying elements.

- Nickel steels
- Nickel-chromium steels
- Molybdenum steels
- Chromium steels
- Chromium-vanadium steels
- Tungsten-chromium steels
- Silicon-manganese steels.

112

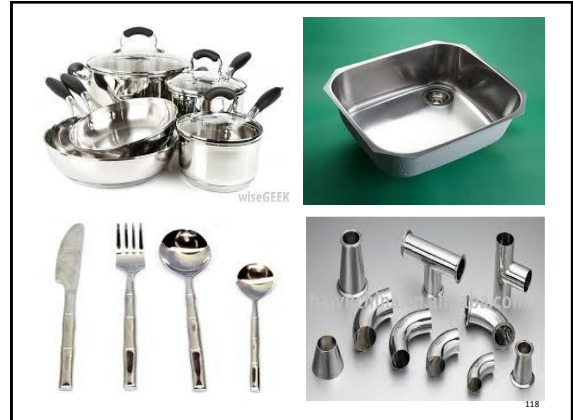
- Structural-grade alloy steels used for construction industries due to high strength.
- Other alloy steels are used for its strength, hardness, resistance to creep & fatigue, and toughness.
- It may heat treated to obtain the desired properties.

113

## ❖ Stainless steels –

- Characterized by their corrosion resistance, high strength and ductility, and high chromium content.
- Combination of high strength & ductility.
- Adding Cr,  $\text{Cr} + \text{O}_2 \rightarrow \text{Cr}_2\text{O}_3$  formation, oxide protects the primary alloy.
- Adding Ni increase corrosion protection (1%).

117



118

## Properties

- Resistance to corrosion
- Low maintenance
- Relatively low cost
- Coils, sheets, plates, bars, wire
- Tubing to be used in cookware, cutlery, surgical instruments, industrial equipment, automotive and aerospace

121

- Storage tanks & tankers used to transport orange juice & other food (corrosion resistance and antibacterial properties)
- Commercial kitchens & food processing plants (steam cleaned, sterilized, no need of painting)

122

## Applications

Kitchen equipments ,  
food container

Soaking tub, die baths



123

New York's Chrysler Building is  
clad with stainless steel



Architectural work



124

## 2. Non-ferrous metals & alloys

- An alloy, not intentionally contain iron.
- Properties of ferrous are not available in Non ferrous alloys.
  - Aluminium and Aluminium alloys
  - Magnesium and Magnesium alloys
  - Titanium and Titanium alloys
  - Copper and Copper alloys
  - Nickel and Nickel alloys
  - Super alloys

125

## Properties

- Light weight, higher ductility
- High strength to weight ratio
- Strength at elevated temperatures
- Corrosion resistance
- Biocompatibility
- Oxidation resistance
- High cost

126

Materials	Density(g cm <sup>-3</sup> )
• Iron	7.87
• Steel	7.80
• Aluminium	2.70
• Magnesium	1.74
• Titanium	4.54
• Copper	8.96
• Zinc	7.13
• Nickel	8.89
• Lead	11.36
• Silver	10.49
• Gold	19.32

127

## Aluminium and its alloys

### Properties

- Light weight
- High corrosion resistance – thin invisible oxide skin is formed on surface (self protecting Characteristic)
- High electrical and thermal conductivities
- High ductility and therefore machinable
- Low melting point (600°C)
- Non Magnetic
- Non toxic – used for cooking applications, Al foil wrapping for foods.

128

## Aluminium and its alloys

### Applications

- Building/construction
- Container
- Packaging
- Transportation
- Electrical conductors
- Machinery/equipment

129

## Applications



130

## Magnesium and its alloys

### Advantages:

- Very low density ( $1.74 \text{ g/cm}^3$ ) lightest metal
- High machinability
- Also has good vibration - damping characteristics

### Disadvantages:

- Expensive
- Difficulty in melting process
- Low wear resistance

131

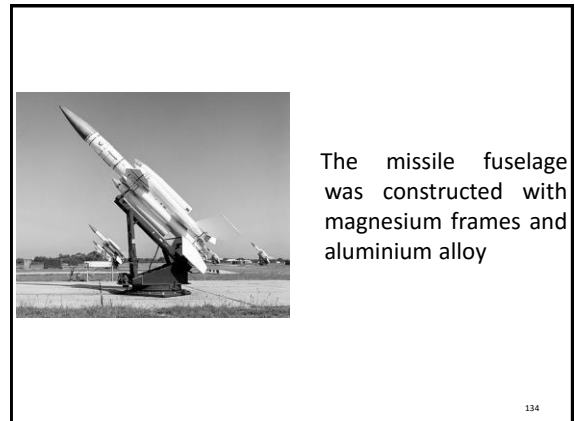
## Applications

- Used as alloying element for Aluminium, steel & ductile cast iron.
- Die casting for aircraft and missile components
- Transport industry

132



133



The missile fuselage was constructed with magnesium frames and aluminium alloy

134

## Titanium and its alloys

### Advantages:

- Medium density ( $4.54 \text{ g/cm}^3$ )
- Titanium alloys have superior specific strength
- High melting point ( $1700^\circ\text{C}$ )
  - Good Corrosion resistance
  - Biocompatibility

137

### Disadvantages:

- Very high cost
- Difficulty in extraction
- Expensive in production

138

## Titanium and its alloys

- Titanium alloys have superior specific strength than steels or aluminium. Good for high strength where space is critical such aircrafts.

Golf sticks and Aerospace flow bodies



139

## Applications

- Structure of high speed aircrafts
- 75% in aerospace
- Medical Applications
- for aircrafts, jet-engines, racing-cars and marine crafts



Turbine blades



Hip-joint component

Turbine blades



141

Aero engine Fan Blades



## Copper and its alloys

### Properties

- High electrical conductivity – cloud of free electrons is uniformly available.
- High thermal conductivity
- High corrosion resistance
- Good ductility and malleability – highly closed packed {111} planes in FCC Crystal structure.
- Reasonable tensile strength
- **Brass** is an alloy of copper and zinc.
- **Bronze** is an alloy of copper and tin.

142

## Applications

- Electrical conductance
- Plating on components
- Heat exchangers
- Copper Nickel alloys & Copper Beryllium alloys have High strength.

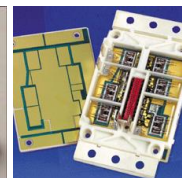
143

## Applications

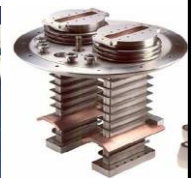
Copper wires



Electronic products



Copper plating



144

Forged Rings



Bullet jackets



145

## Nickel and its alloys

### Properties

- Tough and ductile
- Good high and low temperature strength
- High oxidation resistance
- Good corrosion resistance
- High cost
- Not normally mixed with cheaper alloying metals

146

## Applications

- Applications required necessary corrosion resistance properties (Marine applications)
- Thermocouples – Ni + 45% Cu, develop uniform EMF when couple with another metal.
- High temperature applications, such as jet-engine components & Turbine blades in combustion section
- Resistance wire – Cu+ 45% Ni alloy used for precision resistors.

147

## Applications

Machine parts



Pipes, tubes, bar, wire, sheet, plate, forgings, pipe fittings and flanges

