JECRC Foundation

JAIPUR ENGINEERING COLLEGE
AND RESEARCH CENTRE

JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTER

Year & Sem. – I Year & I SEM
Subject –Basic Mechanical Engineering (1FY3-07)
Unit– 6
Presented by – Dilip kumar Prajapati (Assistant Professor)

VISION AND MISSION OF INSTITUTE

VISION OF INSTITUTE

To became a renowned centre of outcome based learning and work towards academic professional ,cultural and social enrichment of the lives of individuals and communities .

MISSION OF INSTITUTE

Focus on evaluation of learning ,outcomes and motivate students to research aptitude by project based learning.

- Identify based on informed perception of Indian ,regional and global needs ,the area of focus and provide platform to gain knowledge and solutions.
-
- Offer opportunities for interaction between academic and industry .
- Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders may emerge.

VISION AND MISSION OF DEPARTMENT

Vision

The Mechanical Engineering Department strives to be recognized globally for excellent technical knowledge and to produce quality human resource, who can manage the advance technologies and contribute to society through entrepreneurship and leadership.

Mission

1) To impart highest quality technical knowledge to the learners to make them globally competitive mechanical engineers.
2) To provide the learners ethical guidelines along with excellent academic environment for a long productive career.
3)To promote industry-institute linkage.

Course Outcomes of BME

- To describe the importance of mechanical engineering in any industry and to apply the various concepts in thermal based industry.
- To understand the various machines and power transmission related to it and also the effect of parameters on a job.
- To relate the industrial issues with the environment and to consider key concepts in in engineering materials.
- To come across new practices and researches going in mechanical engineering line CAD, CAM etc.

Contents of UNIT-6

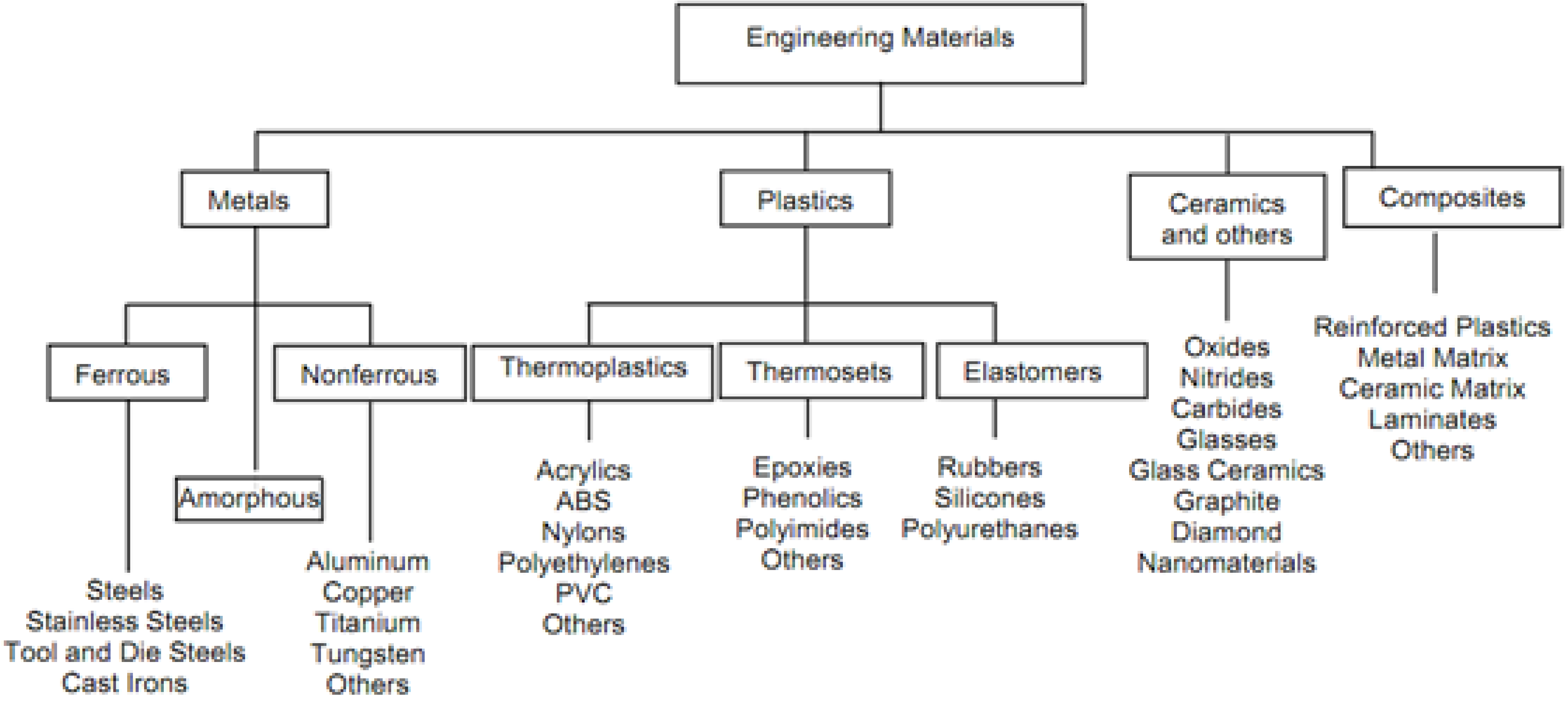
- Engineering materials.
- Heat treatment of steel.

Engineering Materials

Introduction to engineering materials:-

- Materials constitute foundation of technology.
- The history of human civilization evolved from the Stone Age to the Bronze Age, the Iron Age, the Steel Age, and to the Space Age (contemporaneous with the Electronic Age).
- Each age is marked by the advent of certain materials.
- The Iron Age brought tools and utensils.
- The Steel Age brought railroads, instruments, and the Industrial Revolution.
- The Space Age brought the materials for stronger and light structures (e.g., composite materials).
- The Electronic Age brought semiconductors, and thus many varieties of electronic gadgets.
- So it is vital that the professional engineer should know how to select materials which best fit the demands of the design - economic and aesthetic demands, as well as demands of strength and durability.

Classification of Engineering Materials:



- Engineering Materials
  - Metals
    - Ferrous
      - Steels
      - Stainless Steels
      - Tool and Die Steels
      - Cast Irons
    - Amorphous
    - Nonferrous
      - Aluminum
      - Copper
      - Titanium
      - Tungsten
      - Others
  - Plastics
    - Thermoplastics
      - Acrylics
      - ABS
      - Nylons
      - Polyethylenes
      - PVC
      - Others
    - Thermosets
      - Epoxies
      - Phenolics
      - Polyimides
      - Others
    - Elastomers
      - Rubbers
      - Silicones
      - Polyurethanes
  - Ceramics and others
    - Oxides
    - Nitrides
    - Carbides
    - Glasses
    - Glass Ceramics
    - Graphite
    - Diamond
    - Nanomaterials
  - Composites
    - Reinforced Plastics
    - Metal Matrix
    - Ceramic Matrix
    - Laminates
    - Others

Fig. Classification of engineering materials

- **Metals**

The metals might be further classified as:
Ferrous metals and
Non-ferrous metals.

Ferrous metals are those that have iron as the main constituent, such like cast iron, wrought iron and steel, and so on.

N**on-ferrous metals** are those that contain a metal other than iron as their main con stituent, such as, aluminium, copper, brass, tin, zinc, and so on.

- **Non-metals**

Plastics

Thermoplastics
Elastomers
Thermosets

Ceramics
Glass ceramics
Graphite
Glasses
Diamond

- ***Composite Materials***

Reinforced plastics, metal matrix & ceramic matrix composites and honey comb structures - these all materials are also known as engineered materials.

- ***New Materials***

Nanomaterials,
Amorphous alloys,
Shape-memory alloys,
Superconductors

Properties of Engineering Materials:-

The following properties of the materials are of interest to designers and users of engineering products.

1. Mechanical Properties
2. Thermal Properties
3. Electrical Properties
4. Chemical Properties
5. Physical Properties
6. Optical Properties
7. Metallurgical Properties, etc.

Mechanical Properties

Mechanical properties determine the behaviour of the engineering materials under the action of external forces. The mechanical properties of materials include strength; toughness; ductility; stiffness; hardness; and resistance to fatigue, creep, impact, and so on.

Thermal Properties

Thermal properties determine the behaviour of the material in response to the application of heat. It is significant to know the thermal behaviour of the materials utilized in furnaces and boilers since they are exposed to high temperatures.

Electrical Properties

Electrical properties of the material determine their ability to permit or resist the flow of electricity.

Chemical Properties

Many engineering materials in contact with other substances tend to suffer from chemical deterioration; because of chemical reaction between them.

Physical Properties

The term physical property is employed to describe a material under conditions in which external forces are not considered. Physical properties resolve the dimensions, porosity, microstructure of the materials, density and so on.

Optical Properties

Optical properties of the material determine the behaviour of the material under the action of light. Some of the important optical properties are, Refractive index, Absorptivity and Absorption coefficient and Reflectivity.

Metallurgical Properties

Metallurgical properties refer to metallurgical characteristics of materials, e.g. microstructure, grain size distribution, distribution of and state of alloy elements, state of heat treatment, microhardness distribution, and so on.

Mechanical Properties

Brittleness: Ability of a material to break or shatter without significant deformation when under stress; opposite of plasticity, examples:glass,concrete,cast iron, ceramics etc.

Hardness: Ability to withstand surface indentation and scratching (e.g. Brinell hardness number)

 Toughness: Ability of a material to absorb energy (or withstand shock) and plastically deform without fracturing (or rupturing); a material's resistance to fracture when stressed; combination of strength and plasticity.

Stiffness: Ability of an object to resist deformation in response to an applied force; rigidity; complementary to flexibility.

Ductility: Ability of a material to deform under tensile load (% elongation).

Malleability: Ability of the material to be flattened into thin sheets under applications of heavy compressive forces without cracking by hot or cold working means.

Elasticity: Ability of a body to resist a distorting influence or stress and to return to its original size and shape when the stress is removed

Plasticity: Ability of a material to undergo irreversible or permanent deformations without breaking or rupturing; opposite of brittleness.

Creep: The slow and gradual deformation of an object with respect to time.

Fatigue limit: Maximum stress a material can withstand under repeated loading (MPa).

Resilience: Ability of a material to absorb energy when it is deformed elastically (MPa); combination of strength and elasticity.

Tensile strength: Maximum tensile stress of a material can withstand before failure (MPa).

Yield strength: The stress at which a material starts to yield plastically (MPa).

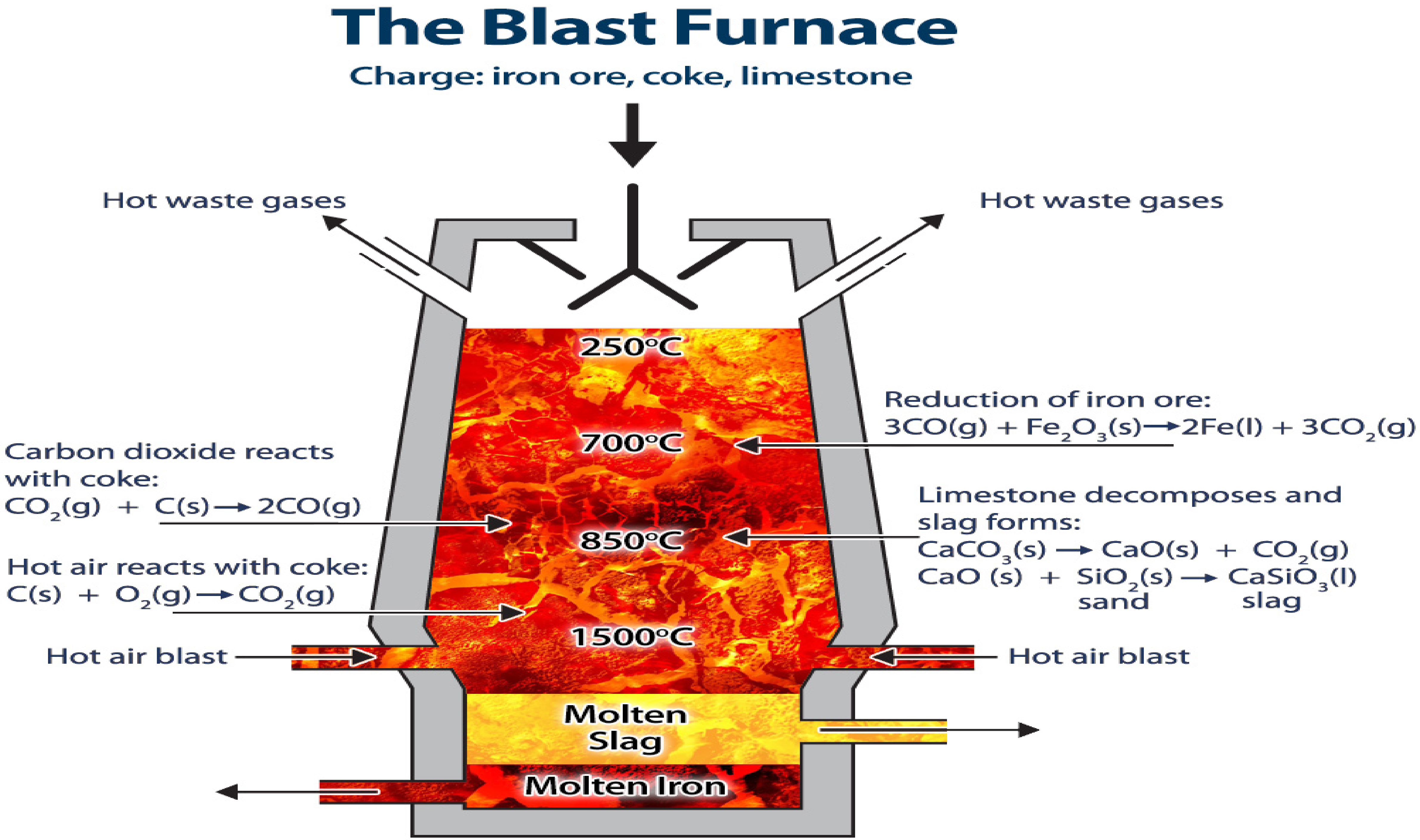
Ferrous metals and its alloys

Ferrous metals include **steel** and pig **iron** (with a carbon content of a few percent) and alloys of **iron** with other metals (such as **stainless steel**).

Pig Iron Pig iron is an intermediate product of the **iron** industry, also known as crude **iron**, which is obtained by smelting **iron** ore in a blast furnace.

Pig iron has a very high carbon content, typically 3.8–4.7%, along with silica and other constituents of dross, which makes it very brittle and not useful directly as a material except for limited applications.

Blast furnace, a vertical shaft furnace that produces liquid metals by the reaction of a flow of air introduced under pressure into the bottom of the furnace with a mixture of metallic ore, coke, and flux fed into the top. Blast furnaces are used to produce pig iron from iron ore for subsequent processing into steel, and they are also employed in processing lead, copper, and other metals. Rapid combustion is maintained by the current of air under pressure.



The Blast Furnace

Charge: iron ore, coke, limestone

Hot waste gases

Hot waste gases

Reduction of iron ore:
$3CO(g) + Fe_2O_3(s) \rightarrow 2Fe(l) + 3CO_2(g)$

Carbon dioxide reacts with coke:
$CO_2(g) + C(s) \rightarrow 2CO(g)$

Limestone decomposes and slag forms:
$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
$\underset{}{CaO(s)} + \underset{\text{sand}}{SiO_2(s)} \rightarrow \underset{\text{slag}}{CaSiO_3(l)}$

Hot air reacts with coke:
$C(s) + O_2(g) \rightarrow CO_2(g)$

Hot air blast

Hot air blast

Fig. The blast furnance

Cast Iron

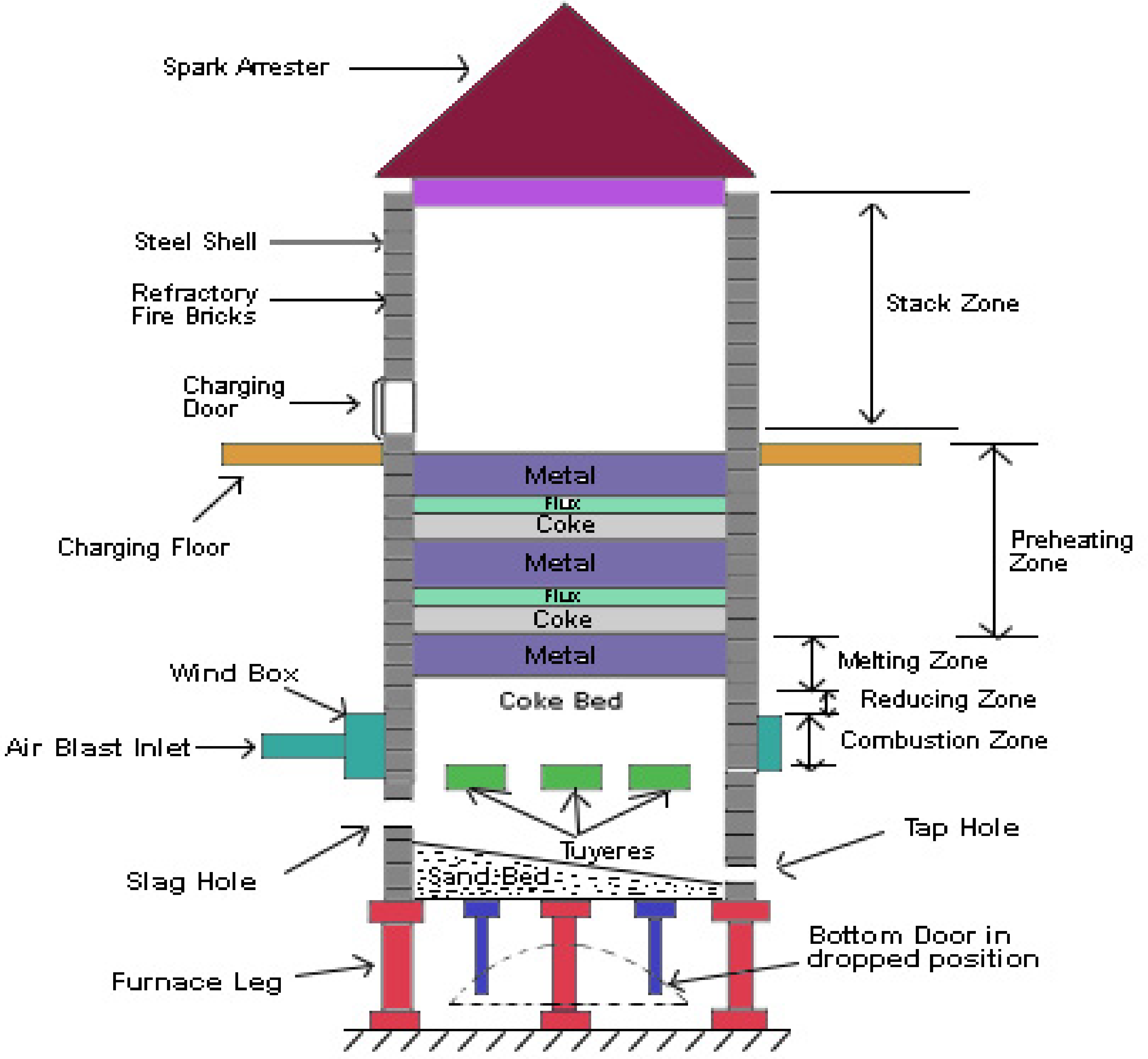
Cast iron is made from pig iron, which is the product of melting iron ore in a blast furnace.

Cast iron can be made directly from the molten pig iron or by re-melting pig iron, often along with substantial quantities of iron, steel, limestone, carbon (coke) and taking various steps to remove undesirable contaminants.

A **cupola** or **cupola furnace** is a melting device used in foundries that can be used to melt cast iron.The size of a cupola is expressed in diameters and can range from 1.5 to 13 feet (0.5 to 4.0 m).

the furnace is filled with layers of coke and ignited with torches. When the coke is ignited, air is introduced to the coke bed through ports in the sides called tuyeres. Wood, charcoal, or biomass may also be used as fuel for the cupola's fire.

Limestone is added to act as a flux. As the heat rises within the stack the metal is melted. It drips down through the coke bed to collect in a pool at the bottom, just above the bottom doors



Cupola Furnace

Fig. Cupola Furnace

Wrought iron

Wrought iron is an **iron** alloy with a very low carbon content (less than 0.08%) in contrast to that of cast **iron** (2.1% to 4%).

Puddling furnace is used to produce wrought iron. In that type of furnace, the metal does not come into contact with the fuel, and so is not contaminated by its impurities .

The heat of the combustion products pass over the surface of the puddle and the roof of the furnace reverberates (reflects) the heat onto the metal puddle on the fire bridge of the furnace.

Raw material used is white cast iron, the pig iron or other raw product of the puddling first had to be refined into refined iron, or finers metal.

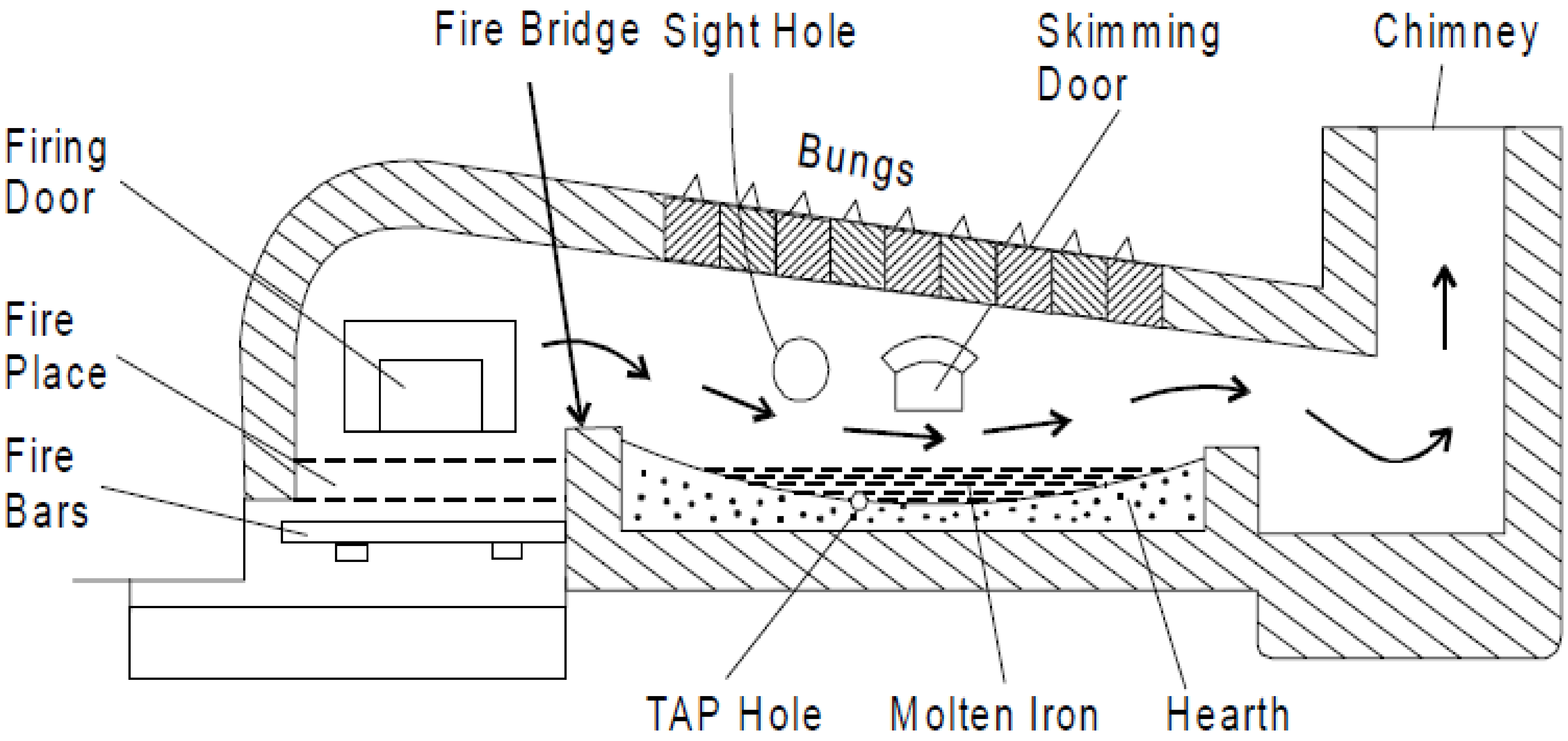


Fig. Puddling Furnace for wrought iron

Steels

Steels are alloys of iron and carbon plus other alloying elements. Alloying additions are necessary for many reasons including: improving properties, improving corrosion resistance, etc.

Classification of steels based on carbon content

Low carbon steels (% wt of C < 0.3):- Carbon present in these alloys is limited, and is not enough to strengthen these materials by heat treatment; hence these alloys are strengthened by cold work.

These alloys are thus relatively soft, ductile combined with high toughness. Hence these materials are easily machinable and weldable.

Typical applications of these alloys include: structural shapes, tin cans, automobile body components, buildings, etc.

Medium carbon steels (0.3 < % wt of C < 0.6):- These are stronger than low carbon steels. However these are of less ductile than low carbon steels. These alloys can be heat treated to improve their strength.

High carbon steels (% wt of C > 0.6):- These are strongest and hardest of carbon steels, and of course their ductility is very limited.

These are heat treatable, and mostly used in hardened and tempered conditions. They possess very high wear resistance, and capable of holding sharp edges.Thus these are used for tool application such as knives, razors, hacksaw blades, etc.

With addition of alloying element like Cr, V, Mo, W which forms hard carbides by reacting with carbon present, wear resistance of high carbon steels can be improved considerably.

Stainless Steels

The name comes from their high resistance to corrosion i.e. they are rustless (stain-less). Steels are made highly corrosion resistant by addition of special alloying elements, especially a minimum of 12% Cr along with Ni and Mo.

Cast irons

Though ferrous alloys with more than 2.14 wt.% C are designated as cast irons, commercially cast irons contain about 3.0-4.5% C along with some alloying additions.

Alloys with this carbon content melt at lower temperatures than steels i.e. they are responsive to casting. Hence casting is the most used fabrication technique for these alloys. Hard and brittle constituent presented in these alloys.

High-Speed Steel

A common type of **high-speed steel** contains **18**% tungsten, **4**% chromium, **1**% vanadium, and only 0.5–0.8% carbon.

It is often used in power-saw blades and drill bits.

Non-Ferrous Materials

Non-ferrous materials have specific advantages over ferrous materials. They can be fabricated with ease, high relatively low density, and high electrical and thermal conductivities.

However different materials have distinct characteristics, and are used for specific purposes. This section introduces some typical non-ferrous metals and their alloys of commercial importance.

Aluminium alloys

These are characterized by low density, high thermal & electrical conductivities, and good corrosion resistant characteristics.

These alloys are ductile even at low temperatures and can be formed easily. However, the great limitation of these alloys is their low melting point (660 C), which restricts their use at elevated temperatures.

Copper alloys

As history goes by, bronze has been used for thousands of years. It is actually an alloy of Cu and Sn. Unalloyed Cu is soft, ductile and One special feature of most of these alloys is their corrosion resistant in diverse atmospheres.

Common most Cu alloys: Brass, alloys of Cu and Zn where Zn is substitutional addition (e.g.: yellow brass, catridge brass, muntz metal, gilding metal); Bronze, alloys of Cu and other alloying additions like Sn, Al, Si and Ni. Bronzes are stronger and more corrosion resistant than brasses.

Applications of Cu alloys include: costume jewelry, coins, musical instruments, electronics, springs, bushes, surgical and dental instruments, radiators, etc.

Magnesium alloys

The most sticking property of Mg is its low density among all structural metals.

Common applications of Mg alloys include: hand-held devices like saws, tools, automotive parts like steering wheels, seat frames, electronics like casing for laptops, camcoders, cell phones etc.

Titanium alloys

Ti and its alloys are of relatively low density, high strength and have very high melting point. At the same time they are easy to machine and forge.

Common applications include: space vehicles, airplane structures, surgical implants, and petroleum & chemical industries.

Refractory metals

These are metals of very high melting points. For example: Nb, Mo, W and Ta. They also possess high strength and high elastic modulus. Common applications include: space vehicles, x-ray tubes, welding electrodes, and where there is a need for corrosion resistance.

Heat treatment of steel

Introduction

Most of the engineering properties of metals and alloys are related to their structure. In practice, change in mechanical properties can be achieved by a process known as heat treatment.

Heat treatment is defined as the heating and cooling operation applied to metals and alloys in solid state in order to obtain the desired properties.

Heat treatment of metal is an important operation in the final fabrication process of many engineering components. The object of this process is to make the metal better suited, structurally and physically, for some specific application.

Purpose of heat treatment

- Improvement in ductility

- Relieving internal stresses
- Refinement of grain size
- Increasing hardness or strength
- Achieving changes in chemical composition of metal surface
- Improvement in machinability
- Alteration in magnetic properties
- Modification of electrical conductivity

Heat treatment furnace

The success of heat treatment depends on proper choice of heat treating furnace. Heat treatment cycles are effective and result in reproducible properties only when other factors like rate of heating or cooling and uniformity of temperature are ensured according to requirement.

This makes the choice of furnace an important aspect in heat treatment practice. The following furnace are normally used:

- Muffle furnace
- Conveyor furnace
- Bath furnace using (a) salt bath or (b) lead bath
- Induction heating furnace

Heat Treatment Processes

- Annealing (a) full annealing (b) stress relief annealing (c) process annealing (d) spheroidise annealing
- Normalising
- Hardening
- Tempering

Stages of Heat treatment

- Heating a metal/alloy to definite temperature
- Holding at that temperature for the required period to allow necessory changes in the structure

- Cooling at a rate necessary to obtain the desired properties

Annealing The term annealing, until and unless specified means full annealing. The heating temperature varies from 750-950^{o}C, holding at this temperature followed by slow cooling.
This process doesnot produce any new structure by phase transformation, but produces new fine grains of the same structure. The various purpose of this treatment are to

- relieve internal stresses developed during solidification, machining, forging, rolling or welding
- Improve or restore ductility and toughness
- Enhance machinabilty
- Eliminate chemical non-uniformity
- Refine grain size
- Reduce the gaseous contents in steel

Normalising The objective of normalising is to secure grain refinement and obtain uniform conditions in materials mechanically treated in various ways as a result of which the grains might have become distorted.

It will also relieve the internal stresses. Thus, the mechanical properties like machi nability, weldability would be improved. This consists of

- Heating temperature varying from 750-975°C
- Holding the work piece for a short period and allowing it to air cool

Normalised steel has higher yield point, tensile strength and impact strength than if they are annealed. But ductility and machinability imparted by normalising will be slightly lower.

Hardening The hardening process is applied to almost all the tools and important machine parts of various types of steel.

It aims to develop high hardness, increased tensile strength, high wear resistance, etc.

The hardening process is accomplished by heating to a temperature between 750 and 950^{o}C , holding it for considerable time, then cooling at a fast rate by quenching in water or oil.

Tempering

The hardening treatment of steels imparts a fine grain size, maximum hardness, minimum ductility and severe internal strains.

Being in an unstable condition, it is unsafe to use. So, to avoid or minimise problems of cracking and distortion, tempering always follows hardening.

The tempering treatment relieves the strain, decrease brittleness and restores ductility and improve toughness.

The conventional method of tempering consists of reheating the hardened steel to a range of temperature which extends from room temperature to 400^{o}C and holding it for a considerable time and then subjecting it to slow cooling.

Difference between annealing and normalising

S. N.	Annealing	Normalizing
1	Heating temperature varies from 750-950°C	Varies from 750-975°C
2	Held at that temperature for a longer period 2 to 4 hours	Held for a shorter period
3	Very slow cooling within the furnace	Fast cooling by air, outside the furnace
4	Material becomes soft, because of slow cooling	Because of fast cooling, material becomes harder and stronger
5	Good improvement in machinability due to increase softness	Some improvement in machinability

Case hardening

Numerous industrial applications require a hard wear-resistant surface called the case. There are five principal methods of case hardening.

- Carburising
- Nitriding
- Cyaniding
- Flame hardening
- Induction hardening

The first three methods change the chemical composition. Carburising is addition of carbon, nitriding is addition of nitrogen and cyaniding is addition of both carbon and nitrogen.

The last two methods are shallow hardening methods. In flame and induction hardening, the steel must be capable of being hardened. Therefore, the carbon content must be more than 0.3%.

Carburising A low carbon steel (0.20% C) is placed in a Carbon monoxide atmosphere. The Carburising temperature is 920°C. At this temperature, the following reaction takes place

$Fe + 2CO \rightarrow Fe(C) + CO$

where Fe(C) represents carbon dissolved in high temperature phase.

Carburising can bedivided into three categories according to the carbonaceous material used, pack carburising, liquid carburising and gas carburising.

Nitriding This is a process for case hardening of alloy steel in an atmosphere consisting of a mixture in a suitable proportions of ammonia gas and dissociated ammonia at 500-570^{o} C.

It is extensively used for aircraft engine parts such as cams, cylinder liners, valve stems, shafts and piston rods.

Cyaniding Cases that contain both carbon and nitrogen produced in liquid salt baths at 760-870°C is called cyaniding.

This process is less time consuming. Because of the high heat transfer coefficient in liquid bath and uniform bath temperature, distortion of pieces is less.

Flame Hardening Selected areas of the surface of a steel are heated from 750 to 950 °C and then quenched to form hard structure. This process consists of moving an oxy-acetylene flame over a part, followed by spray quenching.

The rate at which the flame is moved over the part will determine the depth to which the part is being heated. It is also a function of carbon present in the steel.

Overheating of the work piece should be avoided, otherwise there is the danger after quenching. Tempering is done at about 200°C for flame hardened surfaces.

Induction Hardening Heat is quickly developed by high frequency eddy currents and hysteresis currents on the localized surface of layers.

The primary current is carried by a cooled water tube and the work piece serves as a secondary circuit.

The depth of penetration decreases as the frequency of current increases, Crankshaft of a truck needs a few seconds of heating and spray quenching.

Due to very short cycle time, very little or no distortion is obtained. Typical parts that have been induction hardened are piston rods, pump shafts, spur gears and cams.

References

- http://www.expertsmind.com/topic/materials-used-in-manufacturing/properties-of-engineering-materials-910835.aspx

- https://nptel.ac.in/courses/112/108/112108150/

- https://www.youtube.com/watch?v=hHCRn1U94A0

- https://nptel.ac.in/courses/112/108/112108150/
- Basic mechanical engineering by G Shanmugam and S Ravindran

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