Metallurgical engineering

MET4331

3 credits

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Lecture 1

Metal plays a vital role in almost every aspecMetallurgy is the study of the properties of metals, the physical and chemical behavior of metallic elements, their intermetallic compounds and their mixtures called alloys, and the application of this study to metal recovery, production, purification, and use

t of modern life. It is one of the most important branches of engineering as modern applications nowadays require material with high strength and low weight along with other factors.

Metals are the most recycled material on earth.

Metallurgical Engineers extract, refine and recycle metals.

Metallurgical engineers focus on the production of metals, metallic parts and the properties of those materials. Metallurgical engineers help make products stronger, more durable, lighter weight and more energy-efficient, especially when utilizing recycled materials rather than ores.

They solve many problems such as reducing corrosion, maintaining heat levels and increasing the strength of the product. They help develop or improve metals that are used in healthcare, transportation, defense and entertainment industry.

The work of a metallurgical engineer impacts other engineering fields. They develop core materials that can enhance the function of many products and systems.

The three main branches of Metallurgical Engineering Course are

1) physical metallurgy,
2) extractive metallurgy and
3) mineral processing.

Physical metallurgy deals with problem solving i.e. development of metallic alloys needed for different types of manufacturing and construction.

Extractive metallurgy involves extracting metal from ore.

Mineral processing involves gathering mineral products from the earth’s crust.

What You Learn in course Metallurgical Engineering?

Students will learn about the metals, classification of metals, physical and chemical properties of metals, types of minerals, concentration methods, extraction of metal from minerals, wastes and recycled materials, the design of metallic materials that possess desired mechanical, physical and chemical properties and the production of components from selected metals and alloys.

The main topics of this course are:

- **Minerals processing**
- **Basic Hydrometallurgy**
- **Basic Pyrometallurgy**
- **Electrometallurgy**
- **Corrosion**
- **Powder Metallurgy**
- **Metallurgical analysis**

Learning outcome

- **Provide an understanding of the main chemical and technological principles used in the production of metals from their raw materials. Excercises provide training in practical applications of these principles.**

Early Developments in Metal Extraction

The history of man can be broadly classified into three divisions, namely,

- **the stone age,**
- **the bronze age, and**
- **the iron age.**
- **The transition from the stone age to the metal age - brought about by the discovery of copper in its native form around 8000 B.C. - can be considered one of the most significant phases of human history.**

The period, when man employed both stone and metal, is known as the *chalcolithic* period (GK. *chalcos,* copper; *lithos,* stone).

As is evident from the name, during this period, copper was the chief metal, although man must have located sizeable natural deposits of native metals such as gold and silver. Also, iron and nickel may have been found in the remnants of meteorites that occasionally fall onto the earth's surface from outer space. Copper found ready application in the manufacture of tools and weapons whereas goid and silver served adornment purposes. As time passed, deposits of native copper must have diminished, compelling man to devise new methods for extracting the metal from its ores or to produce its alloy.

The common method for extracting copper from its ores was smelting, i.e., melting or fusing of an ore to separate and refine the metal.

Around 1300 B.C., ore was first subjected to smelting along with a fuel followed by a second smelting, using charcoal together with an air blast, to attain a high temperature needed for the process. Although copper had many useful functional properties, man sought an even harder material for fashioning tools and weapons. He eventually discovered an alloy, namely, bronze, by mixing copper and tin. Thus began the bronze age. Since, as compared with copper, brofize is harder, has a lower melting point, and can be more easily shaped into implements and utensils, it replaced copper.

- **But the bronze age was not to last long; it ended when a new metal - iron - replaced bronze. Since then, man has constantly experimented with metals and has developed, through empirical methods, many standard processes for metal extraction.**

Discovery of Metals

Although man has been using metals since around 8000 B.C., till about the fifteenth century A.D., only a handful of metals was known (e.g., gold, silver, mercury, copper, tin, lead, zinc, and iron); also, some alloys were considered metallic elements.

Further developments in alchemy and the subsequent scientific renaissance accelerated the rate of discovery of metals.

The metals known and used by the Mesopotamians, Egyptians, Greeks, and Romans were copper, tin, gold, silver, mercury, and lead.

In addition to these metals, iron was known and used widely In India as early as 2000 B.C. Of all the metals currently known, nearly three-fourths have been discovered since the beginning of the nineteenth century.

The tollowing factors contributed to the widespread use of the metals

1. Metals such as Au, Ag, Cu, and Hg occur in the natural state. Iron sometimes occurs in meteorites.
2. Oxides of copper, iron, tin, and lead are readily reduced at or below 800°C. Such temperatures are attained easily by burning a carbonaceous material.
3. Pb, Sn, and Hg have a low melting point and are easy to recover.

Such metals sometimes form low melting alloys, e.g., Cu-Sn alloys.

It is interesting to note that till about the twelfth or thirteenth century zinc was unknown in the West although it had perhaps been isolated in India around the ninth or tenth century.

The years/periods now listed are considered significant in the history of extractive metallurgy:

8000 B.C. **Earliest (neolithic) peasant communities of Western Asia start using metallic objects**

4000 B.C. **Egyptians learn to extract copper from its ores**

Chinese start employing flame techniques for producing bronze and iron

2000-1000 B.C. **Indians learn to extract copper from its ores; they also learn to make**

- **bronze with varying tin content**
- **Chinese and Indian artisans master art of casting, riveting, brazing, and forging of copper-tin alloys**
- **Indians and Egyptians learn to wash gold containing sand or crushed and ground rocks; they also learn amalgamation process**
- **Chinese and Indians master iron production by charcoal reduction of iron ores**

1500-0 B.C **West Asians and Indians learn to reduce lead ores by charcoal; also, cinnabar is reduced to produce mercury and purified by squeezing through leather**

- **Silver is produced from impure lead, and tin from its ores**

300 B.C. **Aristotle describes winning of silver from its ores by flame technique**

79 B.C. **Pliny describes preparation of lead by electrochemical displacement and by retort distillation; he also purifies gold by amalgamation**

700-800 A.D. In Europe, copper is precipitated from acid solution with metallic iron

1100-1300 A.D. Alchemists develop inorganic acids for treating ores and metals. Arsenic and antimony are discovered

1550 A.D. Handbooks on metallurgy begin to appear

1700-1800 A.D. Large number of metals are discovered, namely, Co, Pt, Zn, Ni, Bi, Mn, Mo, Te, W, U, Zr, Ti, Y, Be, and Cr

1800-1900 A.D. More metals are discovered, namely, Ta, Ir, Os, Pa, Rh, K, Na, B, Ba, Ca, Mg, Sr, Ce, Li, Cd, Se, Si, Al, Th, V, La, Ru, Rb, In, Ga, rare earths, Ra, Ac, and Po.

- From prehistoric times up to about I860, almost all metals were produced by the fire assay techniques.
- During 1860-1940, the principles of inorganic and physical chemistry were applied, on an organized basis, to metal extraction.
- The pyrometallurgical reduction techniques under controlled conditions using carbonaceous materials and metals were developed and improved upon continuously.

In addition, the electrochemical 'decomposition techniques in aqueous and -nonaqueous media were developed.

Landmarks. The landmarks in the development of modern extractive metallurgy must be examined with respect to the scientific innovations. Some important landmarks are:

Dudley, 1620	Introduces coke to replace charcoal in England
Lavoisier, 1772	Proves invalidity of phlogiston theory and shows that oxides are compounds of metals and oxygen
Wohler, Berzelius Bergman, 1783	Demonstrate hydrogen reduction of $W0_3$ and establish use of hydrogen as reducing agent
Oersted, 1825	Discovers aluminium and shows that alumina is not an element
Nielson, 1828	Uses hot blast to attain high temperatures in blast furnaces
Faraday, 1831	Explains phenomenon of electrolysis and proposes what are today known as Faraday's laws
Bessemer, Kelly, 1856	Introduce pneumatic steel
Woehler, St. Cfeire Deville, 1850	Reduce aluminium salts to metal
Galvani, Volta, Grothans, raraday, Davy, 1850 – appr.	Develop electrochemistry

Answer to the following questions:

- What is Metallurgy?
- What Is Metallurgical Engineering?
- What does a metallurgical engineer do?
- Name the main branches of metallurgical engineering?
- When and what metals were used by man?
- Name some important landmarks of extractive metallurgy?