# BACHELOR OF TECHNOLOGY

## METALLURGICAL ENGINEERING / METALLURGY & MATERIALS ENGINEERING

## THIRD YEAR (FIFTH SEMESTER)

### W.E.F. ADMISSION BATCH 2023-24

| Sl. No. | Category | Course Code | Course | Contact Hrs. L-T-P | Credit | University Marks | Internal Evaluation |
|---|---|---|---|---|---|---|---|
| **Subject (Theory)** | | | | | | | |
| 1 | PC | MTPC3001 | Solidification & Casting of Metals and Alloys | 3-0-0 | 3 | 100 | 50 |
| 2 | PC | MTPC3002 | Mechanical Behavior of Materials | 3-0-0 | 3 | 100 | 50 |
| 3 | PC | MTPC3003 | Non-Ferrous Extraction of Metals | 3-0-0 | 3 | 100 | 50 |
| 4 | PE | MTPE3001 | Alternative Routes of Iron Making | 3-0-0 | 3 | 100 | 50 |
| | | MTPE3002 | Fuels & Refractories | | | | |
| | | MTPE3003 | Secondary Steel Making | | | | |
| | | – | – | | | | |
| | | – | – | | | | |
| | | – | – | | | | |
| | | – | – | | | | |
| 5 | HS | HSHS3001 | Business Management | 3-0-0 | 2 | 100 | 50 |
| | | HSHS3002 | Entrepreneurship Development | | | | |
| 6 | MC | MCMC3001 | Environmental Engineering | 3-0-0 | 2 | 100 | 50 |
| | | MCMC3002 | Industrial Safety Engineering | | | | |
| **Subject (Sessional / Practical)** | | | | | | | |
| 7 | PC | MTPC3201 | Solidification & Casting of Metals and Alloys Laboratory | 0-0-3 | 1.5 | – | 100 |
| 8 | PC | MTPC3202 | Mechanical Behavior of Materials Laboratory | 0-0-3 | 1.5 | – | 100 |
| 9 | PC | MTPC3203 | Non-Ferrous Extraction of Metals Laboratory | 0-0-3 | 1.5 | – | 100 |
| 10 | PSI | MTPS3201 | Seminar on SIRE – I | 0-0-3 | 1.5 | – | 100 |
| | | | **Total** | **18-0-12** | **22** | **600** | **700** |

*Click here to view/download the syllabus of the subjects.*

## HSHS3002 ENTREPRENEURSHIP DEVELOPMENT (3-0-0)

**Course Objectives –**

1. To explain concept of entrepreneurship and build and understanding about business situation in which entrepreneurs act.
2. To explain classification and type of entrepreneurs and the process of entrepreneurial project development
3. To discuss the steps in venture development and new trends in entrepreneurship.
4. The more focus is given on creativity and innovation.

**Module-I: (10 hours)**

Entrepreneurship: Concept of entrepreneurship and intrapreneurship, Types of Entrepreneurs, Nature and Importance, Entrepreneurial Traits and Skills, Entrepreneurial Motivation and Achievement, Entrepreneurial Personality

**Module-II: (08 hours)**

Entrepreneurial Environment, Identification of Opportunities, Converting Business Opportunities into reality. Start-ups and business incubation, Setting up a Small Enterprise. Issues relating to location, Environmental Problems and Environmental pollution Act, Industrial Policies and Regulations

**Module-III: (10 hours)**

Need to know about Accounting, Working capital Management, Marketing Management, Human Resources Management, and Labour Laws. Organizational support services - Central and State Government, Incentives and Subsidies.

**Module-IV: (12 hours)**

Sickness of Small-Scale Industries, Causes and symptoms of sickness, cures of sickness, Role of Banks and Governments in reviving industries.

**Course Outcomes**

After completion of this course, students

CO1: will aware about foundation of entrepreneurship development and its theories
CO2: will identify the type of entrepreneur and the steps involved in a entrepreneurial venture.
CO3: will understand various steps involved in starting a venture and to explore marketing methods & new trends in entrepreneurship.
CO4: Think creative and innovative

**Books:**


1. Entrepreneurship Development and Management, Vasant Desai, HPH
2. Entrepreneurship Management, Bholanath Dutta, Excel Books
3. Entrepreneurial Development, Sangeeta Sharma, PHI
4. Entrepreneurship, Rajeev Roy, Oxford University Press

**MCMC3001 ENVIRONMENTAL ENGINEERING (3-0-0)**

**Course Objectives:**

- To acquire basic knowledge of source of water and various treatment processes
- To determine the sewage quantity, and understand its treatment and disposal
- To Identify and value the effect of the pollutants in atmosphere
- To formulate strategies to solid waste management

**Module-I: (08 Hrs)**

Water: Sources of Water and quality issues, water quality requirement for different beneficial uses, Water quality standards, water quality indices, water safety plans, Water Supply systems, Need for planned water supply schemes, Water demand industrial and agricultural water requirements, Components of water supply system; Transmission of water, Distribution system, Various valves used in W/S systems, service reservoirs and design. Water Treatment: aeration, sedimentation, coagulation flocculation, filtration, disinfection, advanced treatments like adsorption, ion exchange, membrane processes.

**Module-II: (08 Hrs)**

Sewage- Domestic and Storm water, Quantity of Sewage, Sewage flow variations. Conveyance of sewage- Sewers, shapes design parameters, operation and maintenance of sewers, Sewage pumping; Sewerage, Sewer appurtenances, Design of sewerage systems. Small bore systems, Storm Water- Quantification and design of Storm water; Sewage and Sullage, Pollution due to improper disposal of sewage, National River cleaning plans, Wastewater treatment, aerobic and anaerobic treatment systems, suspended and attached growth systems, recycling of sewage – quality requirements for various purposes.

**Module-III: (08 Hrs)**

Air - Composition and properties of air, Quantification of air pollutants, monitoring of air pollutants, Air pollution- Occupational hazards, Urban air pollution automobile pollution, Chemistry of combustion, Automobile engines, quality of fuel, operating conditions and interrelationship. Air quality standards, Control measures for Air pollution, construction and limitations

**Module-IV: (08 Hrs)**

Noise-Basic concept, measurement and various control methods. Solid waste Management-Municipal solid waste, Composition and various chemical and physical parameters of MSW, MSW management: Collection, transport, treatment and disposal of MSW. Special MSW: waste from commercial establishments and other urban areas, solid waste from construction activities, biomedical wastes, Effects of solid waste on environment: effects on air, soil, water surface and ground health hazards. Disposal of solid waste-segregation, reduction at source, recovery and recycle. Disposal methods- Integrated solid waste management. Hazardous waste: Types and nature of hazardous waste as per the HW Schedules of regulating authorities.

**Course Outcomes:**

After successfully studying this course, students will able to:

- Understand the impact of humans on environment and environment on humans
- Identify and value the effect of the pollutants on the environment: atmosphere, water and soil
- Formulate strategies to control, reduce and monitor pollution
- Determine the most appropriate technique for the treatment of water, wastewater solid waste and contaminated air

**Books**


- Introduction to Environmental Engineering and Science by Gilbert Masters, Prentice Hall, New Jersey.
- Introduction to Environmental Engineering by P. Aarne Vesilind, Susan M. Morgan, Thompson /Brooks/Cole; Second Edition 2008.
- Peavy, H.s, Rowe, D.R, Tchobanoglous, G. Environmental Engineering, Mc-Graw -Hill International Editions, New York 1985.
- MetCalf and Eddy. Wastewater Engineering, Treatment, Disposal and Reuse, Tata McGraw-Hill, New Delhi

**MTPC3001 SOLIDIFICATION AND CASTING OF METALS AND ALLOYS (3-0-0)**

**Course Objectives :**

This course aims to provide a comprehensive understanding of metal casting processes, emphasizing their advantages and practical applications. It equips students with knowledge of special casting techniques and industrial melting practices for various alloys. The course explains the principles of gating, risering, and solidification mechanisms in metals and alloys. It also focuses on identifying casting defects and learning methods for their prevention. Overall, it prepares students to design and troubleshoot efficient casting systems in industry

**Module-I: (06 hours)**

Introduction: Casting as a process of Manufacturing. Advantages of casting over other forming processes. A brief mention about mould and its components etc. with special reference to mould factors in metal flow and moulding factors in casting design.

**Module-II: (06 hours)**

Industrial melting practices as adopted for a few metals and alloys such as; Cast-iron; Copper; etc. Principles of Gating and Risering: Types of gates and Risers; Chowrinov rule; Gating ratio, Wlodawer system of determining feeder head requirements. Casting Yield: Various considerations for improving casting yield

**Module-III: (06 hours)**

Special Casting Methods: Investment casting, Die casting, Centrifugal casting, continues casting, Shell moulding, Slush casting etc.

**Module-IV: (06 hours)**

Casting Defects and Their Remedies: Various casting Defects; Their causes and remedial measures.

**Module-V: (06 hours)**

Solidification of Metals and Alloys: Nucleation and growth processes; planar growth and factors hindering planar growth; Dendritic growth; Cellular growth; Heat flow and interface stability in pure metals; Alloy solidification: Solidification of single-phase alloys and solute redistribution during the solidification, Eutectic and Peritectic solidification.

**COURSE OUTCOME:**

CO1: Describe the fundamentals of casting processes and explain the role of mould design and metal flow in determining casting quality.

CO2: Identify and compare various special casting methods such as die casting, investment casting, and centrifugal casting.

CO3: Explain industrial melting practices and apply gating and risering principles for efficient casting design.

CO4: Analyse the solidification mechanisms of metals and alloys including nucleation, dendritic growth, and phase transformations.

CO5: Identify common casting defects, evaluate their causes, and suggest appropriate remedial measures to improve casting yield and quality.

**Books:**


1. Solidification Processing by M.C. Flemings, McGraw Hill.
2. Physical Metallurgy edited by R.W.Cahn and P.Hassen, North Holland.
3. Casting by J. Campbell, Butterworth - Haneman, London


**Reference book:**


1. Principles of Metal Casting by Hein R.W., Loper C. R. & Rosenthal P.C, T.M.H.
2. Foundry Engineering by Taylor H.F., Flemming M.C. & Wulff, Wiley Eastern.
3. Foundry Technology by Beeley P.R., Butterworth, London.

**MTPC3002 MECHANICAL BEHAVIOUR OF MATERIALS (3-0-0)**

**Course Objective:**

To obtain knowledge of the various mechanical properties exhibited by various materials, namely strength, fracture, fatigue and creep. To obtain insight into the different mechanical properties of materials under engineering applications.

**Module-I (06 hrs)**

Theory of elasticity and plasticity, stress-strain relationship,Types of dislocations, their geometrical and elastic properties, Application of dislocation theory to strengthening mechanism and yield point, Strain ageing and work hardening phenomena.

**Module-II (06 hrs)**

Fracture: Fracture behaviour, Griffith`s theory, linear elastic fracture mechanics, fractography, Ductile to brittle transition, Transition temperature phenomena, Factors affecting transition temperature, fracture toughness, strain energy release rate, Stress concentration, stress intensity factor, Crack growth criteria, Mode of deformation, Environment-assisted fracture.

**Module-III (06 hrs)**

Fatigue: Introduction to Fatigue, stress cycles, Cyclic stress-strain behaviour - low and high cycle fatigue, S-N curve, structure feature of fatigue, Fatigue crack propagation, Paris law, Effect of mean stress, stress concentration, size, surface, metallurgical variables and temperature on fatigue.

**Module-IV (06 hrs)**

Creep: Introduction to creep, Creep Curve, Stress Rupture Test, Structural Changes During Creep, Mechanism of Creep deformation, Power Law, Deformation Mechanism Maps, Effect of temperature on creep, Superplasticity, Parametric methods for Prediction of Long Time Properties.

**Module-V (06 hrs)**

Torsion Test: Mechanical Properties in Torsion, Torsional Stresses for Large Plastic Strains, Types of Torsion Failure, Tension Test Vs. Torsion Test, Hot Torsion Testing.

Impact Test: Notched Bar Impact Tests, Instrumented Charpy Test, Significance of Transition Temperature Curve, Metallurgical Factors affecting Transition Temperature Fracture.

**Text Books:**


1. Mechanical Metallurgy, G.W. Dieter
2. Mechanical Behaviour of Materials, M. A. Meyers and K. K. Chawla


**Reference Books:**


1. Mechanical Behaviour of Materials, William F. Hosford
2. Introduction to Dislocations, D. Hull and D.J. Bacon
3. Deformation Behaviour and Fracture Mechanics of Engineering Materials, R. W. Hertzberg
4. Mechanical Behaviour of Materials, Courtney

**MTPC3003 NON-FERROUS EXTRACTION OF METALS (3-0-0)**

**Course Objectives:**

- To explore the fundamentals and various methods used for extraction of non-ferrous metals.
- To describe the procedure and equipment used for production of non-ferrous metals from their ores.

**Module-I: (06 Hrs)**

Metal extraction: Fundamentals, unit processes involved in pyrometallurgy, electrometallurgy and hydrometallurgy.

Sustainable Chemical Metallurgy, Recycling and Recovery from waste. Environmental pollution and its address related to various metal extraction processes in general.

**Module-II: (06 Hrs)**

Aluminum: properties and ores, Extraction using Bayer's process and Hall-Heroult process. Refining of metal: Hoopes process. Indian plant practice. Alternative processes: Alcoa process.

Magnesium: properties and ores. Pidgeon's process. Dows process.

**Module-III: (06 Hrs)**

Copper: properties and ores. Pyro-metallurgical processes. New processes: Flash smelting. WORCRA and Noranda processes. Hydrometallurgical extraction of copper. Copper production in India.

Nickel: properties and ores, pyrometallurgical extraction and refining

Lead: properties and ores. Pyrometallurgical extraction

Zinc: properties and ores. pyrometallurgical and hydrometallurgical extraction methods. Imperial smelting process.

**Module-IV: (06 Hrs)**

Production flow sheets for extraction of Gold and Silver.

Titanium: properties and ores. Extraction and production of Ti sponge.

Tin: properties and ores. smelting and refining.

Chromium: properties and ores, method of extraction from ore and slag.

**Module-V: (06 Hrs)**

Radioactive material extraction: Uranium: Extraction of Uranium. Production flow sheet of Jaduguda ore. Production flow sheets of extraction of Thorium and Plutonium. Zirconium production in India.

**Course Outcome:**

CO1: To understand the fundamentals of non-ferrous metal extraction

CO2: To explore the extraction principles of light metals

CO3: To explore the principle of extraction for base metals

CO4: Demonstrate proficiency of the basic concepts in precious metal extraction

CO5: To acquire knowledge of radioactive material extraction

**Text Books**

1. Ray H.S., Sridhar R. and Abraham K.P., Extraction of Non-Ferrous Metals, Affiliated East – West Press, New Delhi, 2008
2. Dennis W.H., Metallurgy of Non-Ferrous Metals, Sir Isaac Pitman & Sons, 1963

**Reference Books:**

1. Bodsworth C., Extraction and Refining of Metals, CRC Press, 1994
2. Rumbu R., Non-ferrous Extractive Metallurgy - Industrial Practices: 1 (Non-ferrous Metallurgy), Createspace Independent Pub, 2014
3. Rosenquist T., Principles of Extractive Metallurgy, McGraw hill, 1974

**MTPC3201 SOLIDIFICATION AND CASTING PROCESS LABORATORY (0-0-3)**

1. To study the cooling curve of pure metals/ alloys.
2. To study the microstructure of ingot.
3. To study different Phase diagrams for casting of alloys (like Al alloys, Cu alloys, Mg- alloys)
4. Casting of any Aluminium alloys and then study the microstructure of the alloy (Through Optical Microscope and SEM)
5. Casting of any Cu alloys and then study the microstructure of the alloy (Through Optical Microscope and SEM)
6. Casting of any metal matrix composite and then study the microstructure of the composite (Through Optical Microscope and SEM)
7. To compare the microstructure and hardness of Al (or Al alloys) casted in metal and sand mold.
8. To study the casting defects by visual inspection and NDT methods.
9. To study the effects of grain refiners on the cast structure of metals / alloys.
10. To study the effect of superheat temperature and pouring temperature on the microstructure of casting.

**MTPC3202 MECHANICAL BEHAVIOUR OF MATERIALS LABORATORY (0-0-3)**

**Course Objectives**

To provide hands-on experience in evaluating mechanical properties of materials through tensile, compression, wear, fatigue, and creep testing. The lab emphasizes fracture analysis, crack propagation studies, and non-destructive testing techniques to understand material behavior under various loading conditions and microstructural influences.

1. Tensile Testing of Different Materials (Aluminum/ Brass/ Cast Iron)

Compare mechanical properties across different material classes and understand the effect of microstructure on tensile behavior.

2. Compression Test on Metal Specimens
   Study compressive strength, modulus of elasticity in compression, and failure modes.
3. Wear testing of ferrous materials
   Determination of wear resistance of mild steel / low carbon steel in dry condition.
4. Wear testing of non-ferrous materials
   Determination of wear resistance of aluminium / copper / brass in dry condition.
5. Fatigue Testing (Rotating Beam Method)

Study S-N curve generation and determine fatigue limit. Understand crack initiation and propagation under cyclic loading.

6. Creep Test at Elevated Temperature

Measure time-dependent deformation under constant load. Understand primary, secondary, and tertiary creep stages.

7. Fracture behaviour of materials
   Generate ductile and brittle failure and define their toughness.
8. Scanning Electron Microscopy (SEM)
   Study its application in analysing fracture behaviour.
9. Crack Propagation Study
   Observe crack growth using optical methods or strain gauges.
10. Elastic Modulus Measurement by Ultrasonic Method

Non-destructive determination of elastic constants using wave velocity measurements. Compare with static testing results.

11. Poisson's Ratio Determination

Measure lateral and axial strains during tensile testing. Calculate Poisson's ratio and understand volume change behaviour.

**Course Outcomes:**

CO1: Conduct tensile and compression tests to determine key mechanical properties (yield strength, modulus) and compare material performance. (Application)

CO2: Analyze wear resistance of ferrous/non-ferrous materials and correlate results with microstructure. (Analysis)

CO3: Evaluate fatigue life (S-N curves) and creep stages to predict material failure under cyclic/thermal loads. (Evaluation)

CO4: Investigate fracture modes (ductile/brittle) using SEM and crack propagation techniques. (Analysis/Evaluation)

CO5: Apply non-destructive methods (ultrasonic, Poisson’s ratio) to measure elastic constants and validate theoretical models. (Application/Analysis)

**MTPC3203 NON-FERROUS EXTRACTION OF METALS LABORATORY (0-0-3)**

1. To study the Flotation of sulphide ores.
2. To study the thermal decomposition of limestone.
3. To study oxidation and reduction roasting of Cu / Mn /Sn ore.
4. To study cementation of copper.
5. Study the kinetics of roasting of ZnS.
6. To study leaching of Cu/ Pb / Zn/ Mn ore.
7. To study the extraction of Cu from a low-grade ore through hydrometallurgical and electrometallurgical route.
8.` To study the extraction of Zn from a low-grade ore through hydrometallurgical route.

**MTPE3001 ALTERNATIVE ROUTS OF IRON MAKING (3-0-0)**

**Course Objectives**

To explore and analyze alternative iron-making processes beyond traditional blast furnaces, focusing on direct reduction, smelting reduction, and other innovative technologies. The course emphasizes comparative evaluation of these methods in terms of efficiency, environmental impact, and economic viability to prepare students for modern iron production challenges.

1. Tensile Testing of Different Materials (Aluminum/ Brass/ Cast Iron)

Compare mechanical properties across different material classes and understand the effect of microstructure on tensile behavior.

2. Compression Test on Metal Specimens
   Study compressive strength, modulus of elasticity in compression, and failure modes.
3. Wear testing of ferrous materials
   Determination of wear resistance of mild steel / low carbon steel in dry condition.
4. Wear testing of non-ferrous materials
   Determination of wear resistance of aluminium / copper / brass in dry condition.
5. Fatigue Testing (Rotating Beam Method)

Study S-N curve generation and determine fatigue limit. Understand crack initiation and propagation under cyclic loading.

6. Creep Test at Elevated Temperature

Measure time-dependent deformation under constant load. Understand primary, secondary, and tertiary creep stages.

7. Fracture behaviour of materials
   Generate ductile and brittle failure and define their toughness.
8. Scanning Electron Microscopy (SEM)
   Study its application in analysing fracture behaviour.
9. Crack Propagation Study
   Observe crack growth using optical methods or strain gauges.
10. Elastic Modulus Measurement by Ultrasonic Method

Non-destructive determination of elastic constants using wave velocity measurements. Compare with static testing results.

11. Poisson's Ratio Determination

Measure lateral and axial strains during tensile testing. Calculate Poisson's ratio and understand volume change behaviour.

**Course Outcomes:**

CO1: Explain the principles and limitations of conventional blast furnace iron-making versus alternative routes. (Understanding)

CO2: Compare direct reduction (e.g., MIDREX, HYL) and smelting reduction (e.g., COREX, FINEX) processes in terms of energy consumption and emissions. (Analysis)

CO3: Evaluate the role of raw materials (e.g., iron ore pellets, coal, natural gas) in different iron-making technologies. (Evaluation)

CO4: Assess the environmental and economic impacts of alternative iron-making methods. (Evaluation)

CO5: Propose suitable iron-making routes for specific industrial scenarios based on technical and sustainability criteria. (Creation)

**MTPE3002 FUELS AND REFRACTORIES (3-0-0)**

**Course Objectives:**
This course helps students understand different types of fuels and heat-resistant materials used in industries. It teaches how to select and use them efficiently in furnaces and high-temperature processes.

**Module-I: (06 hours)**
Classification of fuels – solid, liquid, gaseous. Primary and secondary fuels. Characteristics of fuels. Fuel selection in metallurgy. Proximate and ultimate analysis of coal. Calorific value, caking, swelling index.

**Module-II: (06 hours)**
Types and ranks of coal. Coal washing – principle, washability curve. Carbonisation – high and low temperature. Metallurgical coke – preparation, properties, testing.
Formed coke, dry quenching.

**Module-III: (06 hours)**
Petroleum and fuel oils. Coke oven gas, blast furnace gas, producer gas, water gas. Natural gas, LPG, CNG. Combustion reactions, air-fuel ratio. Flame temperature, flue gas analysis. Combustion problems, fuel storage safety.

**Module-IV: (06 hours)**
Classification of refractories – acidic, basic, neutral. Raw materials used in refractories.
Bonding types in refractories. Manufacturing processes of refractories. Properties: porosity, bulk density, mechanical strength, thermal conductivity. Thermal properties: Refractoriness Under Load (RUL), spalling resistance, slag resistance. Testing methods as per ASTM/IS standards.

**Module-V: (06 hours)**
Heavy and special refractories: silica, silicide, sialon, high alumina, magnesite, chrome-magnesite, carbon, and insulating refractories. Castable and ramming masses.
Selection of refractories for metallurgical applications: coke oven, iron blast furnace, copper converter, immersion reheating furnaces, heat treatment furnaces, and electric arc furnace. Overview of modern refractory developments and sustainability.

**Course Outcomes:**
After completing this course, the student should be able to:
CO1: Learn about Fundamentals of Fuels
Students will be able to classify different types of fuels and analyze their properties for metallurgical applications.
CO2: Learn about Coal and Coke
Students will be able to explain coal processing methods and evaluate the quality and applications of metallurgical coke.
CO3: Learn about Liquid and Gaseous Fuels
Students will be able to describe various liquid and gaseous fuels and analyze their combustion behavior and safety aspects in metallurgical processes.
CO4: Learn about Refractory Basics and Properties
Students will be able to classify refractories, understand their manufacturing and bonding, and evaluate their properties through standard testing methods.
CO5: Learn about Refractory Applications and Safety
Students will be able to identify special refractories and select suitable materials for various metallurgical furnaces considering performance and sustainability.

**Books:**
1. Fuels, Furnaces and Refractories by J.D. Gilchrist.
2. Fuels, Furnaces and Refractories by O.P. Gupta, Khanna Pulishers
3. Industrial Furnace, Vol –I & II, by Trinks & Mawhinney
4. Refractories manufacture properties and uses by M.L.Mishra

**MTPE3003 SECONDARY STEEL MAKING (3-0-0)**

**Course Objectives:**
This course introduces the principles and practices of secondary steel making.

**Module-I (06 hours)**
Introduction to Ironmaking, Primary steelmaking and Secondary Steelmaking. Steel plant overviews-final products: Primary steelmaking, Raw Materials, Product details, etc.

**Module-II (06 hours)**
Secondary Steelmaking: Objective, techniques like vacuum degassing processes. Ladle degassing processes (VOD, VAD), steam degassing processes, and circulation degassing processes (RH, DH). Process and reaction details.

**Module-III (06 hours)**
Mixing, mass transfer, kinetics, and reaction mechanism study in Steel melts in Ladles. Role of slag and powders in inclusion control, Thermodynamics, and reaction kinetics with preferable conditions for Deoxidation, Desulphurization, Dephosphorization, and Inclusion modification morphologies.

**Module-IV (06 hours)**
Concept of ultra-low carbon, ultra-low sulfur, ultra-low phosphorous, and inclusion-free steels. Stainless steel production through VOD, AOD, and CLS processes.

**Module-V (06 hours)**
Post-solidification treatments (VAR, ESR) for ultraclean steel production. Refractories used in secondary steelmaking furnaces with their properties and selection criteria. Identification, Modification, Cleanliness Assessment of steel, Origin of non-metallic inclusions and its modification, Tundish Metallurgy for Clean Steel.

**Course Outcomes:**
After completing this course, the student should be able to:
CO1: Describe the physical and chemical processes that take place during steel making.
CO2: Analyse the effect of inclusion control on steel properties.
CO3: Describe process selection in secondary steel making.

**Text Books:**
1. Ghosh A., Secondary Steelmaking- principle & Applications, CRC Press.
2. Ghosh A., Principles of Secondary Steelmaking Processing and Casting of Liquid Steel, Oxford & IBH Publication.
3. Yogeshwar Sahai, Toshihiko Emi, Tundish Technology for Clean Steel Production, World Scientific, 2008

**Reference Books:**
1. Ghosh Ahindra, Chatterjee A., Iron making and Steel making Theory and Practices, PHI
2. Dipak Mazumder, James W. Evans, Modeling of Steelmaking Processes, CRC Press

**Reference Books:**
1. Fuels, Furnaces and Refractories by O.P. Gupta, Khanna Pulishers
2. Fuels and Combustion by Samir Sarkar, Orient Longman Ltd., Mumbai.
3. Refractories manufacture properties and application by A.R.Chesti
4. Steel Plant Refractories by Chester
5. Refractories by Norton