National Institute of Advanced Manufacturing Technology,

Hatia, Ranchi-834003

(Centrally Funded Technical Institute, Under MHRD, Govt of India)

(Affiliated under Jharkhand Technical University)

Syllabus

M.Tech (Industrial Metallurgy)

Department of Materials and Metallurgical Engineering

2022

Master of Technology (M. Tech) in Industrial Metallurgy

Programme Objectives:

- Design and develop Metallurgical and Materials Engineering systems to enhance the quality of life
- Choose their careers as practicing metallurgist in manufacturing and service industries.
- To pursue research in the areas of metallurgical engineering
- To work and participate in multidisciplinary environments as well as to develop entrepreneur skills.
- Pursue life-long learning by enhancing knowledge and skills for professional advancement.

Programme Outcomes:

- The industrial metallurgy graduates are capable of applying knowledge of basic sciences, mathematics and engineering in their fields.
- Develop casting and forming process for effective design of industrial components.
- The industrial metallurgy graduates are capable of testing and conduct experiments related to their work as well as to analyze and interpret the results
- Identify techniques for effective and eco-friendly production of iron and steel.
- The industrial metallurgy graduates are capable of doing design and development of processes or system keeping in view of socio-economic aspects.
- The industrial metallurgy graduates are able to apply their knowledge and skills in solving industrial problems effectively
- The industrial metallurgy graduates are capable to utilize the recent cutting edge technologies, innovative practices to develop new technologies
- The industrial metallurgy graduates are capable of developing need basic technologies pertaining to the current industrial requirements of the country

Curriculum Structure

Semester I

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	IM-5101	Physical Metallurgy	3	0	0	3
2	IM-5102	Characterization of Materials	3	0	0	3
3	IM-513*	Programme Elective I	3	0	0	3
4	IM-514*	Programme Elective II	3	0	0	3
5	IM-517*	Open Elective	3	0	0	3
6	IM-5103	Research Methodology and IPR	2	0	0	2
7	IM-5111	Physical Metallurgy Laboratory	0	0	4	2
8	IM-5112	Characterization of Materials Laboratory	0	0	4	2
9	IM-5129	Audit Course I	2	0	0	0
					Total	21

Semester II

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	IM-5201	Metal Casting and Forming Technology	3	0	0	3
2	IM-5202	Modelling, Simulation and Computer Applications in Metallurgy	3	0	0	3
3	IM-525*	Programme Elective III	3	0	0	3
4	IM-526*	Programme Elective IV	3	0	0	3
5	IM-527*	Programme Elective V	3	0	0	3
6	IM-5211	Metal Casting and Forming Technology Laboratory	0	0	4	2
7	IM-5212	Modelling, Simulation and Computer Applications in Metallurgy Laboratory	0	0	4	2

8	IM-5229	Audit Course II	2	0	0	0
9	IM-5221	Mini Project	0	0	4	2
					Total	21

Semester III

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	IM-6122	Dissertation part- I	0	0	20	10
2	IM-6123	Industrial Training		**4 weeks**		0
					Total	10

Semester IV

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	IM-6222	Dissertation part- II	0	0	32	16
					Total	16

Programme Electives - I (3.0.0) Semester I

Serial No	**Course Name**
IM-5131	Secondary steel making process
IM-5132	Metal Joining processes
IM-5133	Inspection & Quality Control
IM-5134	Microstructural Analysis

Programme Electives - II **(3.0.0)** **Semester I**

Serial No	Course Name
IM-5141	Heat Treatment Technology
IM-5142	Processing of Light Metals and Alloys
IM-5143	Tribology of Engineering Materials
IM-5144	Failure Analysis

Open Electives - **(3.0.0)** **Semester I**

Serial No	Course Name
IM-5171	Thermodynamics and Kinetics
IM-5172	Theory of Metal Forming
IM-5173	Principles of Materials Engineering
IM-5174	Numerical methods in Metallurgy

Programme Electives - III **(3.0.0)** **Semester II**

Serial No	Course Name
IM-5251	Materials Selection and Design
IM-5252	NDT Methods
IM-5253	Surface Engineering and Coating Technology
IM-5254	Automotive Materials
IM-5255	High Temperature Materials

Programme Electives - IV **(3.0.0)** **Semester II**

Serial No	Course Name
IM-5261	Corrosion and Prevention of Metals and Alloys
IM-5262	Composites
IM-5263	Forging Die design and Manufacturing
IM-5264	Advanced Powder Metallurgy

Programme Electives - V (3.0.0) Semester II

Serial No	Course Name
IM-5271	Nanostructure Materials
IM-5272	Additive Manufacturing
IM-5273	Industrial Engineering and Operation Management
IM-5274	Deformation Behavior of Materials

Audit Course 1 & 2 (IM-5129 & IM-5229)

1. English for Research Paper Writing
2. Disaster Management
3. Sanskrit for Technical Knowledge
4. Value Addition
5. Constitution of India
6. Pedagogy Studies Stress Management by Yoga and Aerobics
7. Personality Development through Life Enlightenment Skills

IM-5101 Physical Metallurgy

Course content and List of books:

Module 1: Classification of Transformations **Lectures - 3**

Phase transformation of first order and second order, Energy aspects of homogeneous and heterogeneous nucleation, nucleation ratio, fraction transformation at constant rate of nucleation and growth, Nucleation in solids.

Module 2: Recovery, Recrystallisation and Grain growth **Lectures - 3**

Property changes, driving forces, N- G aspects, annealing twins, textures in cold worked and annealed alloys, Polygonization.

Module 3: Austenite – Pearlite and Bainite transformation **Lectures - 4**

Austenite – Pearlite Transformation, role of diffusion and temperature on lamellar spacing. Nature of carbide in Bainite, Upper and lower Bainite, Isothermal transformation in Austempered ductile iron.

Module 4: Martensitic transformation **Lectures - 2**

Crystallographic aspects and mechanism of atom movements, Comparison between twinning and Martensitic transformations; Effect of grain size, Plastic deformation, arrested cooling on kinetics.

Module 5: Order- disorder transformations **Lectures - 2**

Common structures in ordered alloys, variation of order with temperature, determination of degree of ordering, effect of ordering on properties, applications. Spinodal decomposition.

Module 6: Precipitation hardening **Lectures - 2**

Structural changes, mechanism and integration of reactions, effect of retrogression, Double peaks, Spinodal decomposition.

Module 7: Non-Ferrous Alloys **Lectures - 6**

Copper and Copper base Alloys: Phase diagrams of Cu based alloys: brasses, bronzes, Sn Bronzes, Si Bronzes, Al Bronzes, Be Bronzes, Microstructure, Properties and applications of various types of brasses and bronzes, Cupronickel and nickel silvers. Light metal alloys: Classification and temper designation of aluminium alloys, precipitation hardening of Al-Cu system, Modification treatment of Al-Si system, classification, properties and applications: Magnesium & its alloys ,Titanium & its alloys.

Module 8: Polymers, Ceramics and composites **Lectures – 6**

Introduction to polymers – polymerization mechanism, properties of polymers, rubbers, plastics, fibres, biodegradable polymers. Introduction to ceramics, ceramic structures, silicate structures, Processing of ceramics; Properties, glasses and optical fibres. Introduction to composites - classification, metal-matrix, ceramic–matrix and polymer matrix composites.

Module 9: Advanced Materials for emerging applications **Lectures - 5**

Materials for superconductor, sensor and actuator; Green energy materials – hydrogen storage, organic solar cell etc. Biomedical applications – orthopedic, dermatological and denture applications.

Reference Books:

1. Raghavan, V., Phase transformations, Prentice Hall

2. Smallman, R.E., Modern physical metallurgy

3. Reed Hill, R.E., Principles of physical metallurgy, Affiliated East West Press.

4. Sinha A.K., Physical Metallurgy Handbook, McGraw Hill.

5. S. H. Avner, Introduction to Physical Metallurgy, Tata McGraw-Hill Education, 1997.

Course outcomes (COs):

Upon completion of this class, the students will be able to:

CO1: Evaluate critically the relevance of phase diagrams, isothermal transformation diagrams and continuous cooling transformation diagrams to understand real alloys and their microstructure.

CO2: Apply the fundamentals of phase transformation to steels and other engineering materials.

CO3: Display a critical awareness of the relevance of key areas, e.g., diffusion, defects, transformation type, to current problems in designing, processing and exploiting real alloys.

CO4: Define and differentiate engineering materials on the basis of structure and properties for engineering applications.

CO5: Select proper processing technologies for synthesizing and fabricating different materials.

CO6: Analyze the microstructure of metallic materials using phase diagrams and modify the microstructure and properties using different heat treatments.

CO7: Describe the mechanisms responsible for atomic and molecular movements in condensed phases.

IM-5102 Characterization of Materials

Course content and List of books:

Module 1: Introduction to Materials Characterization Techniques Lectures 6

Different techniques and their purposes; Optical Microscopy (OM) - Introduction, Optical principles, Instrumentation, Types of OM, Fundamentals of Imaging: magnification, resolution, Numerical Aperture, depth of field and depth of focus, Airy disk, Rayleigh criterion, Imaging Modes, aberration, Specimen preparation-metallographic principles, Applications, Limitations.

Module 2: Scanning Electron Microscopy (SEM) Lectures 8

Introduction to Electron Microscopy, Types of electron guns and lenses, aberration, Interaction of electrons with specimen, interaction volume, Construction and working principle of SEM, Operational variables, imaging modes-Secondary electron, back scattered mode of imaging, Types of SE and BSE detectors, Sample preparation, surface charging and its preventions, Applications, Limitations.

Module 3: Transmission Electron Microscopy (TEM) Lectures 8

Introduction, Principle, construction and operation of TEM, Imaging modes-bright and dark field imaging, diffraction mode, selected area diffraction, Indexing of SAD pattern, Contrast Mechanisms- mass density contrast, diffraction contrast, phase contrast, preparation of specimens, Applications, Limitations.

Module 4: Chemical analysis Lectures 4

Energy Dispersive Spectroscopy (EDS) and Wavelength Dispersive Spectroscopy (WDS): Instrumentation, Working procedure, Applications, Advantages, Limitations.

Module 5: X- Ray Diffraction and Spectroscopy Lectures 4

X-ray diffraction: powder diffraction, phase identification, Scherrer formula, strain and grain size determination; Characteristics of X-rays, X- ray Fluorescence Spectrometry

Module 6: Scanning Probe Microscopy (SPM) **Lectures 6**

Introduction to SPM, Types of SPM: Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM) - Basic principle, Instrumentation, operational modes, Applications, Limitations.

Module 7: Thermal Analysis **Lectures 4**

Instrumentation and principles of differential scanning calorimetry (DSC), differential thermal analysis (DTA), Thermogravimetric analysis (TGA), Dilatometry, Applications, Limitations.

Readings:

1. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods - John Wiley & Sons (Asia) Pte Ltd, 2008

2. ASM Handbook: Materials Characterization, ASM International, 2008.

3. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.

4. S.J.B. Reed: Electron Microprobe Analysis, Cambridge University Press, London, 1975.

5. B.D. Cullity, S.R. Stock, "Elements of X-Ray Diffraction", Pearson; 3 edition, 2001

6. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.

Course Outcomes (COs)

At the end of the course, students will be able:

CO1: an understanding of, image formation by glass and electromagnetic lenses, the physics of scattering, the construction of various types of electron microscope, the function of the various parts and methods of image formation. This course teaches the students to use light microscope (LM), the scanning and transmission electron microscope (SEM & TEM), and X-ray diffraction and scattering.

CO2: describe the theories and construction of TEM, SEM and reflection optical microscope (OM), the factor that control the resolution, interference, and contrast mechanism. An understanding of methods of sample preparation for SEM and TEM.

CO3: calculate intensities of microscope image of a one-dimensional diffractions grating using bright-field, dark-field, and phase contrast apertures.

CO4: Given a powder specimen of a materials with simple crystal structure, be able to collect analyze and understand powder diffraction data. Be able to use Ewald sphere construction, and calculations of structure factors to predict diffraction conditions and intensities from a three-dimensional crystal. Be able to calculate estimate of x-ray mass absorption coefficient at x-ray energies.

CO5: to calculate estimates of AES, XRF, EELS etc. and able to utilize EDS, and WDS results for micromechanical analysis. Upon completion of the course, the students will be able to suggest common characterization techniques for the characterization of surfaces, particles, crystal structures, and microstructures, analyze the information such as methods give and relate it to current methods for the modification of materials.

IM-5131 Secondary Steel Making Process

Course content and List of books:

Module 1 **Lectures 4**
Objectives of secondary steel making. Various processes.

Module 2 **Lectures 4**
Vacuum ladle degassing, Recirculation Degassing (RH) – brief outline. Recirculation Degassing with oxygen top lance (RH-OB) - brief outline, D-H process – principle and working.

Module 3 **Lectures 4**
Ladle preparation & preheating for secondary steel operations, refractories required to withstand the temperatures, advances in refractories for improved life. Ladle Degassing (VD, Tank Degassing) - brief outline. Ladle-to-mold degassing - brief outline. Deoxidation of steel - - brief outline . Ladle Furnace (LF) - brief outline.

Module 4 **Lectures 4**

Vacuum Oxygen Decarburization (VOD) – principle and operation, Argon - oxygen decarburization (AOD) – basic principle, operation and application.

Module 5 **Lectures 8**

Thermodynamics & kinetics of deoxidation. types & selection of deoxidizers, metallurgical & thermodynamic conditions for good desulphurization and synthetic slag. wire injection techniques for increased efficiency of deoxidation &desulphurization. practical aspects in handling of liquid steel and safety precautions to be adopted in industry.

Module 6 **Lectures 8**

Specific stirring power of igp and types of porous plugs, Stoke's law for floatation of oxide inclusions. exogenous & endogenous inclusions. modification of inclusion morphology. thermodynamics of degassing of liquid steel. tank degassing vs circulatory degassing. stream degassing for vacuum teeming of ingots. performance indices for clean steel.

Module 7 **Lectures 8**

Deoxidation by metallic deoxidizers - Killed steels , Semi-killed steels , Rimmed steels - Deoxidation by vacuum . Diffusion deoxidation , Desulfurization of steel , Electroslag Remelting (ESR) - . - brief outline, vacuum arc remelting – brief outline.

Reading:

1. Modern Steel Making --- Dr. R.H.Tupkary .

2. Steel Making -- A.K.Chakrabarty -- PHI .

3. Physical Chemistry of Iron & Steel making --- R.G.Ward .

4. Manufacture of Iron & steel , Iron Production – Vol – I ,II & III --- G.R. Bashforth.

5. Secondary Steel Making: Principles & Applications, Ahindra Ghosh, CRC Press.

Course outcomes (CO_s):

CO1-Develop clear understanding of the concept of clean steels – their characteristics and importance

CO2-Understand the fundamentals and practices of secondary steel making processes

CO3-To appreciate the science and technology of stainless steel making

CO4-Appreciate and evaluate Mass balance, thermodynamic parameters, kinetics etc. of reactions and processes

IM-5132 Metal Joining Processes

Course content and List of books:

Module 1: Basics of Materials Joining **Lectures 8**

Introduction: Theory and classification of welding and other joining processes. Manual metal arc (MMA): equipment requirement, electrodes for welding of structural steels, coating, constituents and their functions, types of coatings, current and voltage selection for electrodes for welding, power sources; conventional welding transformers, rectifiers, current and voltage. The influence of power sources on welding, metal transfer, chemical heat source, heat flow in welding, fluid flow in weld pool, constitution supercooling

Module 2: Arc Welding **Lectures 12**

Submerged arc welding (SAW): process details, consumables such as fluxes and wires for welding mild steel, variations in submerged arc welding process.

Gas metal arc welding or MIG/MAG welding: process details, shielding gases, electrode wires, their sizes and welding current ranges.

TIG Welding: process details, power source requirements, electrode sizes & materials, current carrying capacities of different electrodes, shielding gases, applications

Module 3: Resistance welding **Lectures 8**

Resistance welding: General principle of heat generation in resistance welding, application. Process details & working principles of spot, seam, and projection welding. Electrode materials, shapes of electrodes, electrode cooling, selection of welding currents, voltages.

Module 4 **Lectures 4**

Weld defects, Fatigue of weld joints, Hydrogen cracking

Module 5 **Lectures 8**

Welding metallurgy of carbon and alloy steels, cast irons, stainless steels, Al-and Cu- based alloys. Soldering & Brazing: difference between both the processes, consumables used, methods of brazing, fluxes used, their purposes and flux residue treatment.

Reference Books:

1. Lancaster J.F., Metallurgy of Welding, Allen, and Unwin.

2. Little R.L., Welding and Welding Technology, TMH.

3. Norrish J., Advanced Welding Processes, Woodhead.

4. Wenman K., Welding Processes Handbook, Woodhead

5. Sindo Kou – Welding Metallurgy, 3rd Edition

6. ASM Handbook on Welding and Joining, Vol.6

Course outcomes (COs):

At the end of course students will be able to

CO1: Metallurgical changes exist in weld metal and its effect on properties.

CO2: The purpose and classification of coating of the electrodes

CO3: The various types of modes of metal transfer exist in welding processes.

CO4: The difference between various welding processes and its industrial utilization.

IM-5133 Inspection & Quality Control

Course content and List of books:

Module 1: **Lectures 8**

Basic Concepts of Quality Control; Quantity Costs and Their Control; Quality Policies and the Marketplace; Role of Statistical Methods, Statistical parameters for quality assurance; Prediction of process or product quality using normal distribution. Need of Inspection, Inspection types and Principles, Design for Inspection

Module 2: **Lectures 8**

Sampling inspection: Plastic selection of sampling schemes for attributes and variables; Use of control charts for attributes and variables.

Module 3: **Lectures 8**

Destructive tests including fracture toughness testing. Non destructive methods of inspection for castings, forgings and weldments; Radiography, ultrasonic, magnetic particle, eddy current, die penetrant, holography,

Module 4: **Lectures 4**

optical microscopy, photo micrography; Fracture tests;

Module 5: **Lectures 8**

Principles of automatic inspection, test and assembly vision systems. Monitoring of production equipments, elements of fault diagnostics, Statistical Process Control (SPC).

Module 6: **Lectures 8**

Thermocouple Calibration, UTM Calibration, Hardness tester calibration, Failure analysis, Analysis of castings, forgings & welding defects, Testing of Composite Materials, Quality Audits, Case Studies.

Reference Books:

1. Banga, T.R and Sharma, S.C, Industrial organization and Engineering economics, Khanna publishers
2. Khanna, O.P, Industrial Engineering and Management, Dhanpat Rai and Sons.
3. Halmshaw, R, Non destructive Testing, Gordon and Breach
4. Baldevraj, Jay Kumar and T, Thavasimuthu, M, Practical Non destructive Testing, Narosa Publishers.

Course outcomes (COs):

At the end of course students will be able to

CO1: Understand the basic theories and concepts in quality control.

CO2: Get the insight into process improvement, statistical methods and the role of quality in manufacturing

CO3: Get acquainted with the inspection planning, calibration systems, sampling, quality tools including SPC, and their implementation.

CO4: Process the industrial quality data and come to inferences which can be implemented as corrective and preventive actions.

IM-5134 Microstructural Analysis

Course content and List of books:

Module 1: **Lectures 6**

Conventional metallographic techniques, and applications of microstructural analysis in failure investigations and in material performance tests, environmental degradation, and welding qualification testing, Concepts of microstructural elements and texture; microstructure-texture control strategies during manufacturing; microstructural design of multicomponent alloys; processing-microstructure-texture-properties in alloys

Module 2: **Lectures 12**

Different types of surface characterization techniques, Optical emission spectroscopy, X-Ray diffraction: Diffraction under non-ideal conditions, atomic scattering and geometrical scattering factors, and analysis, Fundamentals of Optics: variants in the optical microscopes and image formation, Electron microscopy (TEM-SEM): principle of electron microscopy, construction and operation, concepts of backscatter and secondary electron, diffraction and image formation, sample preparation and applications

Module 3: Lectures 8

Fractography: specific information about the conditions and cause of a fracture, Location and nature of flaws including material or manufacturing defects, crack initiation sites and direction of propagation, and the type of stress and load direction.

Module 4: Lectures 8

Failure analysis: metallographic examination of the constitution and structure of metals and alloys to detect material microstructures, Flaws, and abnormalities to determine the metal failure, Preventing future failures, pits and cracks in metallic materials

Module 5: Lectures 6

Extent of decarburization and carburization, grain size, intergranular attack or corrosion, Depth of alpha case in titanium alloys, Percent spheroidization, Inclusion ratings, Volume fraction of various phases or second phase particles in metals

Reference Books:

1. Microstructural Characterization of Materials by David Brandon and Wayne D. Kaplan, John Wiley & Sons
2. P.J. Goodhew, J. Humphreys, R. Beanlands, Electron Microscopy and Analysis, 3rd Edition, Taylor and Francis, London.
3. Microstructure Characterization, Edited by E. Metcalfe, The Institute of Metals, USA.
4. B.D. Cullity, Elements of X-ray Diffraction (For X-rays), 3rdedition, Prentice-Hall, Upper Saddle River 2001.
5. Thomas & M.T. Gorringe, Transmission Electron Microscopy of Materials, John Wiley, 1979.
6. L.E. Murr, Electron and Ion Microscopy and Microanalysis, Marcel Dekker, 1991.
7. Douglas B. Murphy and Michael W. Davidson, Fundamentals of Light Microscopy and Electronic Imaging, John Wiley & Sons, Inc.
8. Williams, David B., Carter, C. Barry, Transmission Electron Microscopy - A Textbook for Materials Science, Springer, 2009.
9. Courtney, T.H., Mechanical Behavior of Materials, Second Edition, Overseas Press, New Delhi (India), 2006
10. ASM Handbook Vol 19: Fatigue and Fracture, ASM International, USA, 1996.

Course outcomes (COs):

At the end of course students will be able to

CO1: learn what tool to use for materials analysis/characterization.

CO2: familiar with all major techniques for analysis of microstructural features

CO3: Recognize practical consideration and limitations of each technique.

CO4: identify potential problems and give insight into the effects of processes such as welding and machining on a materials microstructure.

IM-5141 Heat Treatment Technology

Course content and List of books:

Module 1: **Lectures 4**

Classification of alloying elements and their effects on Iron–Iron carbide phase diagram, TTT Diagram and CCT Diagram, General Heat treatments such as Annealing, Normalizing, 18 Hardening, Tempering, Austempering, Martempering, Hardenability concept, Stages of Quenching and their effects, Types of quenching media such as oils, polymers; Cooling characteristics of quenching media, Control of quenching parameters, quenching fixtures, Dimensional changes during hardening and tempering.

Module 2: **Lectures 4**

Heat treatment to commercial alloys steels-1: Heat treatment of Low alloy steels, Free cutting steels, Spring steels; bearing steel, Tool Steel: Selection criteria and properties of Tool steels, Classification of Tool Steels: Cold work, Hot Work Tool Steels, High Speed Steels and Stellites.

Module 3: **Lectures 4**

Heat treatment of aluminium alloys, magnesium alloys, Ni-base super alloys and Ti alloys

Module 4: **Lectures 4**

Thermo-mechanical treatments; DP steels, TRIP steels and TRIP assisted Steels, QP steel TWIP steels, Hardenability, thermo-chemical and thermo-mechanical and thermo cycling treatments; Failure analysis of heat treated products.

Reference Books:

1. Raghavan, V., Phase transformations, Prentice Hall

2. Sharma R.C., Principles of Heat Treatment of Steels, New Age International.

3. Sinha A.K., Physical Metallurgy Handbook, McGraw Hill.

4. Singh V., Heat Treatment of Metals, Standard Publishers.

5. ASM Metals Handbook – Heat treatment, Metals Park Ohio Pub.

6. K.E Thelning, Steel and its Heat Treatment, Butterworth, London

Course outcomes (COs):

Upon completion of this class, the students will be able to:

CO1: Interpret the different heat treatments (annealing, normalising, quenching, tempering).
CO2: Analyze the microstructure of metallic materials using phase diagrams and modify the microstructure and properties using different heat treatments.
CO3: Describe the mechanisms responsible for atomic and molecular movements in condensed phases
CO4: Understand the heat treatment of steels and determine the heat treatment conditions required to obtain a given microstructure using TTT and CCT diagrams

IM-5142 Processing of Light Metals and Alloys

Course content and List of books:

Module 1 **Lectures 8**
General introduction - strengthening by solid solution, precipitation, dispersion of second phase particles, grain refinement and work hardening.

Module 2 **Lectures 12**
Aluminum and its alloys: Production of Aluminum, Designation, temper and characteristics of cast and wrought alloys. Heat treatment of Aluminum alloys – Al-Si, Al-Cu, Al-Mg & Al-Zn-Mg systems. Development of high strength Aluminum alloys by non-equilibrium processing routes

such as rapid solidification and powder metallurgy. Applications in consumer, automotive and aerospace industry.

Module 3 **Lectures 12**

Magnesium and its alloys: Production of Magnesium, Designation, temper and characteristics. Heat treatment of Magnesium alloys – Mg-Sn, Mg-Zn, Mg-Gd, Mg-Li systems. Development of high strength magnesium alloys. Applications in consumer, automotive and aerospace industry.

Module 4 **Lectures 8**

Titanium and its alloys: Production of titanium. Heat treatment of Titanium and its alloys - alpha alloys, alpha - beta alloys, beta alloys. Applications in sports, automotive, aerospace and strategic industries.

Reading:

1. I. J.Polmear, Light Alloys - From Traditional alloys to nanocrystals, Fourth Edition, Butterworth Heinemann, 2005

2. R.W.Heine, C.R.Loper, P.C.Rosenthal, Principles of Metal Casting ,Tata McGraw Hill, 1976.

3. D.H. Kirkwood, M. Surey, P. Kapranos, H.V. Atkinson, K.P. Young, Semisolid Processing of Alloys, Springer Series in materials Science, 2010.

4. M. Gupta, N.M.L. Sharon, Magnesium, Magnesium Alloys, and Magnesium Composites, Wiley, 2011

5. G. Lutjering, J.C. Williams, Titanium, Springer, 2007

6. T.W. Clyne, P.J. Withers, An introduction to metal-matrix composites, Cambridge University Press, 1993.

Course Outcomes:

At the end of course students will be able to

CO1: understand various routes of synthesis of light metals and alloys

CO2: understand the physical metallurgy of aluminium alloys

CO3: analyze the effect of microstructure on mechanical properties of various light metals and alloys and relate both the parameters to the recent trends in applications of light metals and alloys

CO4: understand the effect of alloying elements on microstructure, physical properties and mechanical properties of Magnesium alloys and Titanium alloys

IM-5143 Tribology of Engineering Materials

Course content and List of books:

Module 1: **Lectures 6**

Importance of wear, friction & Lubrication Friction, Solid friction; Fundamentals, basic theories and mechanism; types of friction: sliding and rolling; friction in metals, alloys and composites; effect of parameters affecting friction; measurement of friction; frictional heating and calculations

Module 2: **Lectures 6**

Contact of engineering surfaces: Hertzian and non-hertzian contact, contact pressure and deformation in non-conformal contacts, causes of friction, stick-slip friction behavior and friction instability, sliding and rolling friction, frictional heating and temperature rise, wear and wear types, mechanisms of wear; wear map.

Module 3: **Lectures 6**

Introduction to wear; surface damage; types of wear: solid-solid, solid-liquid and solid gas such as adhesion, abrasion, slurry erosion, cavitation erosion, liquid impingement erosion, fretting, erosion-corrosion, types of contacts: sliding, rolling; worn surface topography, debris analysis and wear mechanism mechanisms; parameters affecting wear, relevant ASTM standards.

Lubrication

Module 4: **Lectures 8**

Lubricants & additives, mechanism of solid, liquid and gaseous lubricants. Friction and wear of different components

Module 5: **Lectures 8**

Solid and rolling contact bearings, gears, seals, dynamic pistons, cylinders, connecting rods, push rods, drive shafts, brakes, IC engine parts, drive chains, cutting tools, dies and electrical contacts. Materials for friction and wear applications, Cast irons, carbon and alloy steels, stainless steels, bearing steels, tool steels, hard facing alloys, aluminum alloys, intermetallic, and composites.

Readings

1. Wear of metals by A.D.Sarkar, Pergamon Press, Oxford
2. Engineering Tribology by Prasanta Sahoo, PHI Learning Pvt Ltd, New Delhi
3. Principles and Applications of Trobology by Bhushan B, John wiley and Sons, New York 4.2
4. Friction and Wear of Materials by Rabinowicz.E,Jphn Wiley nd Sons, New York
5. Engineering Tribology by Williams. J.A, Oxford University Ptress, New York.

Course Outcomes:

At the end of course students will be able to

CO1: Define different types of wear and wear modes in tribology.

CO2: Classify different wear measurement techniques to interpret material wear behavior.

CO3: Select suitable material combination for improved tribological performance.

CO4: Recommend suitable material system for desired operating window in tribology domain.

IM-5144 Failure Analysis

Course content and List of books:

Module 1 **Lectures 8**

Strength of Materials, Elastic and plastic behaviour, Concept and classification of fracture, Theoretical cohesive strength of metals, Griffith's crack theory, Stress intensity factor, Stress analysis of cracks, Strain energy release rate, Derivation of relationship between strain energy release rate and stress intensity factor, crack tip plastic zone, Dugdale's plastic strip model, Modes of fracture, Fractography

Module 2 **Lectures 8**

Fracture mode transition: Plane stress vs. plane strain, Crack opening displacement, Plane strain fracture toughness (KIC) testing, Fracture toughness determination with elastic plastic analysis (JIC), Concept of R-curve and Fracture toughness measurement using it, Microstructural aspect of fracture toughness, Optimizing microstructure and alloy cleanliness to enhance fracture toughness, Temper embrittlement, Ductile to brittle transitions

Module 3 **Lectures 8**

Fatigue stress life approach, Basquin's equation, Fatigue strain life approach, Low cycle fatigue, Cofin-Manson's equation, Fatigue total strain life relation, Fatigue life prediction, Fatigue crack growth rate, Paris law, Fatigue life calculation using this approach. Mechanism of fatigue crack nucleation and propagation, Factors affecting fatigue crack growth rate, Influence of stress concentration, Surface effects and fatigue, Effect of metallurgical variables on fatigue properties, Design for Fatigue, Corrosion fatigue.

Module 4 **Lectures 6**

High temperature materials problem, Creep test, Creep curve, Structural change during creep, Creep mechanisms, Stress-rupture test, Larsen-Miller parameter, Creep resistant materials, Effect of metallurgical variables on creep.

Module 5 **Lectures 10**

Types of failure and techniques for failure analysis, Failure data retrieval, Procedure steps for investigation of a failure, Failure analysis methodology, Tools and Techniques of Failure analysis, Reliability concept and hazard function, life prediction, Condition monitoring, Application of Poisson, Exponential and Weibull distributions for reliability, Bath tub curve, Parallel and series system, Mean time between failures and life testing.

Some case studies of failure analysis. Introduction to quality management, concept of ISO 9000, ISO 14000, QS 9000; Inspection; Inspection by sampling

Reference Books:

1. Hertzberg, R.W., Deformation and fracture mechanics of engineering materials, John Wiley.

2. Dieter, G.E., Mechanical Metallurgy, McGraw Hill
3. Metal Hand book, Failure analysis and prevention (Volume- XI), ASM Pub.
4. Metal Hand book, Fractography (Volume- XII), ASM Pub.
5. J. S. Collins, Failure of Materials in Mechanical Design, A Wiley Interscience Publication, 1993.
6. T. L. Anderson: Fracture Mechanics-Fundamentals and Applications, 3rd Edition, CRC Press, 2011.
7.Michael Kassner: Fundamentals of Creep in Metals and Alloys, 2nd Edition, Elsevier Science, 2009.
8. Colangelo V.J. & Heiser F.A., Analysis of Metallurgical Failures, John Wiley.

Course Outcomes

Upon completion of this class, the students will be able to:

CO1: Correctly apply fracture mechanics to predict brittle fracture. Identify and describe the basic fracture, creep and fatigue mechanisms

CO2: Understand crack resistance and energy release rate for crack criticality

CO3: Correctly identify the cause of failure of a material based on fracture surface observations

CO4: Awareness about crack formation and crack growth in materials under various conditions

CO5: To understand the concepts of materials failure and fracture and should be able to analyze and take remedial steps in case of failure by fracture

CO6: Understand factors responsible for failure of materials. Differentiate fracture modes and failure mechanisms for ductile, brittle, fatigue, and creep failure

CO7: Determine fracture toughness of brittle and ductile materials. Predict life of materials under fatigue loading. Analyze failure through case studies and select tools for failure analysis

CO8: The course provides the methods for prevention of failure in terms of materials selection, design and surface and metallurgical variables.

IM-5171 Thermodynamics and Kinetics

Course content and List of books:

Module 1: Introduction to thermodynamics **Lectures 6**

Thermodynamics systems, Classification, thermodynamic variables, State functions, Process variables, Extensive and intensive properties, Energy and first law of thermodynamics, Heat capacity, Enthalpy, Heat of reactions, Hess‟s law, Kirchhoff's equation, Thermochemistry, Le-Chatelier principle.

Module 2: Law of thermodynamics and related applications Lectures 12

Second law of thermodynamics, Entropy, Effect of temperature on entropy, Statistical nature of entropy, Combined statements of first and second law of thermodynamics, Gibb's free energy, Helmholtz's free energy, Maxwell's equations, Gibbs-Helmholtz equation, Clausius-Clapeyron"s equation and its application to phase changes, Free energy as criterion for equilibrium and its applications to metallurgical reactions, Third law of thermodynamics. Activity, Equilibrium constant, Joule-Thompson effect, Chemical potential, Law of mass action, Effect of temperature and pressure on equilibrium constant, Vant Hoff‟s isotherm, Free energy temperature diagrams, oxygen potential and oxygen dissociation pressure.

Module 3: Introduction to solutions Lectures 8

Introduction to solutions, Partial molar quantities, Gibbs- Duhem relations, thermodynamic aspects of metallic solutions and salt melts, Raoult's and Henry's Law, quasi-chemical models for regular solutions.

Module 4: Thermodynamic aspects of phase diagrams Lectures 8

Gibb‟s phase rule and its applications, Free energy composition diagram, Thermodynamic aspects of phase diagrams, theoretical and experimental determination of phase diagram, similarity in thermodynamic approach towards different classes of materials, thermodynamic aspect of defect formation in metals and ceramics.

Module 5: Principles of metallurgical kinetics Lectures 6

Principles of metallurgical kinetics, reaction rates, order of reaction and reaction mechanism, determination of order of reactions, Arrhenius equation, collision theory and absolute reaction rate theory.

Reference Books:

1. Gaskell, David, R., Introduction to Metallurgical Thermodynamics, McGraw Hill.

2. Mohanty, A. K., Rate processes in metallurgy, Prentice Hall of India.

3. Upadhayaya, G.S., and Dube, R.K., Problems in metallurgical thermodynamics and kinetics, Pergamon 4. Darken, L.S., and Gurry, R.W., Physical chemistry of Metals, McGraw Hill.

4. Ahindra Ghosh, "Text book of Materials & Metallurgical Thermodynamics", Prentice Hall India, 2009.

Course outcomes:

Upon completion of the course, the student will be able to

CO1: Understand the basic laws of thermodynamics and concepts such as the theory of solutions, free energy, entropy, criteria for equilibrium and conditions for feasibility

CO2: Understand the multiple approaches to thermodynamics, from the bulk property point of view and from the atomistic point of view

CO3: Obtain the skill to use metallurgical thermodynamic concepts and equations for understanding phase diagrams, phase transformations, theory of solutions

CO4: Obtain problem solving skills in order to improve / modify industrial processes, esp. In extraction metallurgy, liquid metal treatment and in heat treatment

CO5: Understand the concept behind rate of chemical reactions and order of chemical reactions

CO6: Understand concepts behind the determination of phase diagrams with the help of thermodynamic principles.

IM-5172 Theory of Metal Forming

Course content and List of books:

Module 1 **Lectures 4**

Introduction and Classification of metal forming processes. Concept of stress and strain. Description of stress, state of stress in 3D. Description of strain, Hydrostatic and deviator components of stress and strain.

Module 2 **Lectures 12**

Theory of plasticity and Flow curve for materials. True stress and true strain. Yield criteria for ductile materials. Yield locus, Octahedral shear stress and strain. Plastic stress strain relationships. Measures of yielding and ductility in tensile testing, Instability in tension, Strain rate effects on flow properties. Temperature effects on flow properties. Influence of various parameters on flow properties.

Module 3 **Lectures 12**

Classification of metal working processes, Mechanics of metalworking and analysis methods. Determination of flow stresses in metal working. Hot working and cold working. Metallurgical considerations in metal forming.

Introduction and classification of forging processes. Equipment used in forging. Forging in plane strain, forging defects.

Introduction and classification of rolling processes. Types of rolling mills Analysis of rolling load calculations. Rolling variables. Defects in rolling.

Module 4 **Lectures 8**

Introduction and classification of extrusion processes, Analysis of extrusion processes, Extrusion of tubes and pipes, extrusion defect.

Introduction to rod and wire drawing. Analysis of wire drawing and tube drawing processes drawing defects.

Sheet metal forming: Forming methods such as bending, stretch forming, shearing, blanking, deep drawing and redrawing. Formability diagrams, Defects in formed products. Special forming methods such as high energy forming: explosive forming, electrohydraulic and magnetic forming processes

Reference Books:

1. Dieter G.E., Mechanical Metallurgy, McGraw Hill.

2. Harris J.N., Mechanical Working of Metals- Theory and Practice, Pergamon. 23

3. Kalpakjian S. and Schmid S.R., Manufacturing Processes for Engineering Materials, Pearson.

Course outcomes (COs)

CO1: Understand and apply the mechanism of deformation for different metal forming processes and develop analytical relation between input and output parameters of process.

CO2: Understand and analyze the concept of yield criteria applicable to different material deformation processes.

CO3: Apply theoretical and experimental techniques for measurement of important outcomes of metal forming processes.

IM-5175 Principles of Materials Engineering

Course content and List of books:

Module 1: **Lectures 7**

Introduction: Solid Engineering Materials- their classification and characteristic properties. Structure of solids: crystal systems/lattices, crystal structure, crystallographic planes and directions, interstitial sites, crystalline metals, ceramics, semiconductors and polymers.

Module 2: **Lectures 7**

Microstructures and metallography; Amorphous or glassy state; Solidification of pure metal: homogeneous and heterogeneous nucleation processes, cooling curve, concept of supercooling, microstructure of pure metals.

Module 3: **Lectures 7**

Defects in solids: point, line, planar and volume defects. Fundamentals of plastic deformation of metals, deformation by slip and twin, plastic deformation in polycrystalline metals, concept of cold working, preferred orientation; Annealing: recovery, recrystallization and grain growth; hot working;

Module 4: **Lectures 7**

Properties of materials: Definition, units and common tests conducted to evaluate important engineering properties like physical, mechanical, chemical, electrical, magnetic, semi/super-conducting, optical, and thermal properties in engineering materials; Concept of formation of alloys: Types of alloys, solid solutions, factors affecting solid solubility, order-disorder transformation;

Module 5: **Lectures 7**

Binary phase diagrams: isomorphous, eutectic, peritectic, eutectoid and peritectoid systems, effect of non-equilibrium cooling: coring and homogenization; Iron-cementite phase diagram: Construction and interpretation of Fe-Fe3C and Fe-Graphite diagrams. Microstructure, and properties of different alloys in steel and cast iron, types of cast iron, their microstructures and typical uses; Heat treatment: T-T-T and C-C-T diagrams, concept of heat treatments of steel: annealing, normalizing, hardening and tempering; microstructural effects brought about by these processes and their influence on mechanical properties.

Module 6: **Lectures 7**

Effect of common alloying elements in steel, concept of hardenability, factors affecting it; Common alloy steels, stainless steel, tool steel, high speed steel, high strength low alloy steel, micro-alloyed steel, specifications of steels; Physical metallurgy of common non-ferrous alloys: Cu-,Al- and Ni- based alloys. Microstructures and heat treatment of common alloys of these systems; Engineering ceramics and polymers: Structure, properties and application of common engineering ceramics and polymers.

Texts / Reference Books:

1. William D. Callister, Jr.Materials Science and Engineering, Wiley India (P) Ltd.
2. V.Raghavan, Materials Science and Engineering: A First Course 5th Ed, Prentice Hall of India, New Delhi (2000).
3. Sidney H. Avner, Introduction to Physical Metallurgy, Tata McGraw-Hill.
4. Butterworth-Heinemann, Michael Ashby, Hugh Shercliff and David Cebon, Materials Engineering, Science, Processing and Design

Course Outcomes

At the end of the course, students will be able to:

CO1-Be able to apply core concepts in Materials Science to solve engineering problems.

CO2-Interpret about material fundamental and material processing.

CO3-Distinguish the defects in crystal and its effect on crystal properties.

CO4-Figure out the different mechanical properties of material by studying different destructive and non- destructive testing.

CO5-Articulate and utilize corrosion prevention strategies and estimate corrosion behavior of materials and components

CO6-Acknowledge the importance of surface modification and study the different surface modification methods.

CO7-Perceive the basics of Powder metallurgy and application of powder metallurgy

CO8-Select proper metal, alloys, nonmetal, and powder metallurgical component for specific application requirement

IM-5176 Numerical methods in Metallurgy

Course content and List of books:

Module 1: Errors in Numerical Methods **Lectures 2**

Approximate numbers and Significant figures; Rouding-off numbers; Errors: Absolute, Relative and Percentage; Error in Arithmetical operations; A General Error Formula; Errors in Numerical Computations; Inverse Problems.

Module 2: Solution of equations in one variable **Lectures 6**

Bisection method; Iteration method; Regula-Falsi method; Convergence of Regula-Falsi method; Secant method; Newton-Raphson method; Generalised Method for multiple roots; Rate of Convergence of Newton‘s square root formula; Newton‘s Inverse formula; Graffe‘s Root-Squaring method; Ramanujan‘s method; Rate of Convergence and. Computer Programmes for the above methods;

Module 3: Numerical solution of system of equations **Lectures 4**

Gauss elimination method; Gauss-Jordan method; Jacobi‘s iteration method; Gauss Sidel method; Ill conditioned problems; Error analysis; Computer programs based for the above methods.

Module 4: Operators and Difference Equations **Lectures 5**

Forward difference operator, Backward difference operator, Shift operator, Average operator, Central difference operator and their relations; Factorial Notation; Synthetic division; Missing Term Technique; Basic ideas of Difference Equations.

Module 5: Interpolation **Lectures 6**

Newton‘s forward interpolation formula; Newton‘s backward interpolation formula; Stirling‘s Formula; Bessel formula; Lagrange‘s interpolation formula; Divided differences; Newton‘s divided difference formula; Numerical differentiation and applications; Central Difference Interpolation Formulae; Gauss‘ Forward central Difference Formula; Gauss‘ Backward central Difference Formula; Computer Programs for the above formulas.

Module 6: Numerical integration **Lectures 6**

A general quadrature formula for equidistant nodes; Trapezoidal rule; Simpson‘s one-third rule, Simpson‘s three-eight rule; Wedddle‘s rule; Inherent errors in numerical integrations; Newton-Cotes quadrature formula; Euler-Maclaurin formula; Gaussian quadrature formula; Flow charts, Algorithms and Computer Programs to implement the above techniques.

Module 7 Numerical Methods of Solution of O.D.E **Lectures 8**

Picard's Method of Successive Approximations ; Picard's Method for Simultaneous First Order Differential Equations; Euler's Method;; Modified Euler's Method; Runge-Kutta method; Flow-charts, algorithms and computer programs for the above methods.

Reference Books:

1. Dipak Mazumdar, James W. Evans- Modelling of Steel Making Processes, CRC Publication,1st Edition,2010
2. H.K.Versteeg , W.Malalsekera-An Introduction to Computational Fluid Dynamics, Longman Scientific & Technical, 1st Edition 1995.
3. S.C.Chapra,R.P.Canale-Numerical Methods for Engineers, McGraw Hill India Pvt. Ltd.,5th Edition,2007

Course Outcomes:

At the end of the course, students will be able to :-

CO1 : Understand the various numerical methods and their applicability for various processes.

CO2 : Relate the models with on field real shop floor practices.

CO3 : Predict/extrapolate situations using various numerical methods.

CO4 : Develop insight of the physical & chemical principles of the processes

IM-5103 Research Methodology and IPR

Module 1: **Lectures 5**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

Module 2: **Lectures 5**

Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations Effective literature studies approaches, analysis Plagiarism , Research ethics

Module 3: **Lectures 5**

Effective technical writing, how to write report, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Module 4: **Lectures 5**

Introduction to Intellectual property and its role in the growth and development of technology, R & D sector. Discussion on various treaties, protocols and agreements executed between different states to facilitate IPR services. (Eg: trIPS, GATT, Madrid Protocol, PCT, etc.), Various economic factors related to the IP Rights and their importance in business strategies, Different types of IPR, including copyright, patent, and trademark, and their legal protections, Agencies responsible for enforcement, patent, trademark, or copyright policies.

Reference Books:

1. Stuart Melville and Wayne Goddard, "Research methodology: An Introduction for Science and Engineering Students", Juta and Company Ltd.

2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction", Juta and Company Ltd, 2004.

3. Ranjit Kumar, "Research Methodology: A Step-by-Step Guide for Beginners", SAGE Publications, 2nd edition, 2005.

Course Outcomes:

At the end of the course, students will be able to

CO1: Understand research problem formulation.

CO2: Analyze research related information.

CO3: Follow research ethics.

IM-5111 Physical Metallurgy Laboratory

List of Experiments: [Any 08 Experiments]

1. Preparation of specimens for microscopic examination: steels, copper alloys and aluminium alloys, cast irons.

2. Study of etching mechanism of single phase and two phase alloys and preparation of etching reagents for plain carbon steel, cast iron, copper base alloys and aluminium alloys.

3. Study of Metallurgical microscope.

4. Observation and drawing of different morphologies of grains: equiaxed dendrites, columnar dendrites, cellular structure, equiaxed grains, polygonal grains, elongated grains.

5. Grain size measurement by ASTM comparison method, Heyn's Intercept method, Jefferies planimetric method.

6. Observation of microstructures using image analyzer, Quantitative Metallography software, models and tools for grain size, shape, phases distribution and porosity.

7. Observation and description of microstructures of annealed plain carbon steels.

8. Observations and description of microstructures belonging to various cast irons.

9. Observations and description of microstructures belonging to various brasses, bronzes, wrought and cast aluminium alloys.

Laboratory Outcomes:

At the end of laboratory work, Students will demonstrate the ability to:

1. Prepare the samples for microscopic examination and understand the concepts of quantitative metallography.

2. Identify the microstructures of various ferrous and nonferrous alloys and develop structure and properties correlation for various applications.

3. Analyze the microstructures of different metals and alloys using optical microscopy and image analysis software for characterization

IM-5112 Characterization of Materials Laboratory

List of Experiments: [Any 08 Experiments]

1. To determine grain size of ferrous and nonferrous alloys using various techniques
2. Microhardness measurement of ferrous and nonferrous alloys
3. To study dilatometry to determine linear coefficient of thermal expansion (LCTE) of different materials
4. Study of Different Types of Symmetry in Cubic Lattices
5. To study stereographic and standard projections to evaluate crystal orientation problems
6. To determine high temperature resistivity of various materials.
7. XRD: Indexing a diffraction pattern from cubic materials.
8. To study surface morphology and fractography by Scanning Electron Microscopy
9. X ray diffraction analysis to determine the retained austenite content in the sample.
10. X ray analysis to determine the residual stresses in formed sample.

Laboratory Outcomes:

At the end of course students will be able to

CO1: Understand, use, and compare various characterization equipments for conducting microstructure and grain size evaluation.

CO2: Apply the knowledge of crystal structure and X ray diffraction to determine the lattice constant, crystal structure and quantify the retained austenite and residual stresses in a sample.

IM-5201 Metal Casting and Forming Technology

Course content and List of books:

Module 1: **Lectures 10**

Basic sand casting process, pattern, mould, core, gating, riser, casting yield, Classification of casting processes, Types of Foundries, General layout and sections in foundries, Patterns and

Cores – Selection of parting line, allowances on pattern, pattern materials, color coding, core plates, core-boxes – metallostatic pressure, design of core print, chaplets

Module 2: **Lectures 10**

Mold making - Green sand moulding, dry sand moulding, molding sands, Properties of foundry 51 sands and their testing, additives, Sand Control, core sands, mould compaction machines, Jolt, Jolt-squeeze, high pressure molding, sand slinger, refractory coatings, Venting, molding boxes, chills, roll of additives & technical terms in sand like total clay, active clay, latent clay, dead clay. Materials used for vacuum impregnation seals. Materials used for vacuum impregnation seals .

Module 3: **Lectures 10**

Fundamentals of fluid flow, design of gating system, slag traps and filters etc. Risering curves, NRL, Caine method, Gating systems and their characteristics. Directional and progressive solidification, differential methods of feeder design, feeding distance, feeding efficiency. Nature and causes of Casting defects, their remedial measures, Aluminum alloy, Magnesium alloy, copper alloy and special alloy foundry practice.

Module 4:. **Lectures 10**

Basics of metal forming, hot, cold and warm working of metals, strain rates in metal forming, an overview of elementary stress analysis and yield criteria, description and analysis of various bulk forming processes (forging, extrusion, wire drawing and rolling), concept of Workability. Understanding the influence of alloying elements, temperature and cooling rates post deformation processing (recovery, recrystallization, and grain growth) on the evolution of microstructure and properties.

Reference Books:

1. Heine R.W., Lopper C.R. & Rosenthal P.C., Principles of Metal Casting, McGraw Hill.
2. Davis, G.J., Solidification in Casting, Applied Sciences.
3. Beeley P.R., Foundry Technology, Butterworth.
4. Kondic V., Metallurgical Principles of Foundry, Edward Arnold

5. Harris J.N., Mechanical Working of Metals- Theory and Practice, Pergamon. 23
6. S. Kalpakjian and S. R. Schmid. (2003) Manufacturing Engineering and Technology, Pearson Education
7. M. P. Groover. (2005) Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, 2nd edition, John Wiley & Sons

Course outcomes (COs)

At the end of the course, students will be able to:

CO1: Have the basic knowledge for pattern design.
CO2: Have an Understand the technology variables and complexity involved in producing a core.

CO3: To impart knowledge about principles/methods of casting with detail design of gating/riser system needed for casting
CO4: To inculcate the principle, thermal and metallurgical aspects during solidification of metal and alloys.

IM-5202 Modelling, Simulation and Computer Applications in Metallurgy

Course content and List of books:

Module 1: **Lectures 6**
Modelling: Classification, functions, limitations and interrelationship of different types of models. Types and development of mathematical models. Development of rigorous and semirigorous physical models. Multi-scale modelling of materials. Phase-field methods for modelling solidification microstructures of metals and alloys

Module 2: **Lectures 6**
Simulation: Survey of simulation techniques. Molecular dynamics and Monte-Carlo simulations. Fuzzy logic, neural networks and genetic algorithms.

Module 3: **Lectures 6**

Applications: Computation of phase diagrams using solution models and Monte-Carlo simulations.Modelling of blast furnace operations, steel making processes and materials processing.

Module 4: **Lectures 6**

Basics of computer programming, introduction to computation, numerical methods, physical of modelling of material problems, scales in materials structure, length and time scales in modelling

Module 5: **Lectures 6**

Monte-Carlo Methods: basics and applications, molecular modelling: inter atomic potential

Module 6: **Lectures 6**

Introduction to FEA and crystal plasticity: basics, solving 1D and 2D problems

Module 7: **Lectures 6**

Microstructure modelling, thermodynamic modelling: CALPHAD, ThermoCalc, alloy design, integrated computational materials engineering, materials selection and design.

Readings

1. Richard Laser, Introduction to Computational Materials Science, Cambridge University Press, 2013.

2. R J Arsenault, J R Beeler Jr, D M Easterling (Eds): Computer Simulation in Materials Science, ASM International, 1986.

3. Zoe Barber, Introduction to Material s Modelling, Maney Publishing, 2005.

4. June Gunn Lee, Computational Materials Science 2ed., CRC Press, 2016

5. B.S. Grewal, Numerical Methods in Engineering and Science, Mercury Learni

6. J.S.Szekely, J.W. Evans and J.K. Brimakombe: The Mathematical and Physical Modelling of Primary Metals Processing Operations, Wiley.

7. D. Mazumdar and J.W. Evans: Modelling of Steel Making Processes, CRC

Course Outcome

Upon completion of this class, the students will be able to

CO1: Understand the importance of computational modelling in developing and designing new materials.

CO2: Predict the properties and performance of materials based on the simulation data and understanding its relevance for the experimentation.

CO3: Understand the physical and chemical properties of complex materials by FEM and continuum mechanics.

IM-5251 Materials Selection and Design

Course content and List of books:

Module 1 **Lectures 12**

Revision of engineering materials, Classification of materials- metals and alloys, ceramics, polymers and composites, Importance of materials selection and metallurgical design, Properties and applications of plain carbon steels and common non-ferrous alloys.

Module 2 **Lectures 10**

Criteria for selection of materials, Ashby charts for materials selection, application of statistics in materials.

Module 3 **Lectures 14**

specification of steels, Composition, heat treatment, microstructure and properties of ferrous and non-ferrous alloys, ceramics and polymers for light and heavy structural, corrosion resistant, high temperature, low-temperature and cryogenic, wear resistant, magnetic, electrical and electronic applications, pressure vessels and boilers, bearings, tools, medical implants and prostheses application, Composites, shape memory alloys, metallic glasses, nanocrystalline materials.

Reading:

1. M.F. Ashby: Engineering Materials, 4th Edition, Elsevier, 2005.
2. M.F. Ashby: Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.
3. ASM Publication, Vol.20: Materials Selection and Design, ASM, 1997.

4. Pat L. Mangonon: The Principles of Materials Selection and Design, Prentice Hall International, Inc.1999.

Course Outcomes

At the end of the course, students will be able to:

CO1: To provide the students a thorough systematic approach to the selection of metals, ceramics, polymers, and composites required for mechanical design

CO2: To familiarize the students with material properties and materials fabrication processes and an approach for selecting a process capable of producing a component possessing the size, shape, properties, and cost dictated by the design.

CO3: To teach students how to deal with multiple constraints and conflicting objectives including realistic constraints involving the economics, environment, manufacturability, and sustainability.

CO4: To introduce the students to the methodologies for designing new materials and conceiving hybrid solutions

IM-5252 NDT Methods

Module 1 **Lectures 8**

Introduction of NDTs: Introduction: Testing and its types, Brief description about NDE/NDT (Scope, advantages, limitations, and applications), Role of NDT in quality control, NDT codes and standards, Basic principle, types, and characteristics methods. evaluation, advantages, limitations and applications of visual optical methods, dye penetrate testing, 49 Remote Visual Inspection (RVI), NDT related competences: Non-destructive testing Qualification and certification of NDT personnel (ISO 9712:2012)

Module 2 **Lectures 8**

Electromagnetic testing (ET): Basic theory of magnetism, Magnetization & demagnetization methods, Types of ET, Magnetic-particle inspection (MT or MPI): testing procedures and equipment's, (ISO 9934, ASTM E- 709), Applicable standards & acceptance criteria, Factor affecting MPI, Advantages, limitations, and applications, Advanced ET like Alternating current field measurement (ACFM), Alternating current potential drop measurement (ACPD), Direct current potential drop measurement (DCPD), Magnetic flux leakage testing (MFL), Remote field testing (RFT), Eddy Current Testing (ECT)

Module 3 **Lectures 8**

Eddy current testing: Basic principles and applicable laws, Conductivity of a material, Self and mutual inductance, Impedance plane, Skin effect, Techniques used for ECT, Coli arrangements, Types of circuit, Inspection probes, Eddy current testing procedures and equipment's, Applicable standards & acceptance criteria, Factor affecting ECT, Advantages, limitations, and applications, Advanced ECT like Pulsed Eddy Current (PEC), Remote Field Eddy Current (RFEC)

Module 4 **Lectures 8**

Radiographic testing (RT): Basic principles of radiography, Radiation sources, Effect of radiation in film, radiographic, imaging, image formation, image quality, image interpretation, radiation shielding,, digital radiography, Inspection procedures and equipment's, Type of display and display system, Applicable standards & acceptance criteria, Factor affecting RT, Advantages, limitations, and applications, Protection against radiation, Advanced ECT like Real Time Radiography (RTR) / Digital Radiography, computed radiographic testing, Neutron imaging, SCAR (small, controlled area radiography) X-ray computed tomography (CT)

Module 5 **Lectures 8**

Ultrasonic Testing (UT): Basic principles of UT, basics of ultrasonic waves, pulse and beam shapes, ultrasonic transducers Generation of ultrasound, Characteristics of an ultrasonic beam; Probe construction Inspection procedures and equipment's, Types of display and display system, Applicable standards & acceptance criteria, Factor affecting UT, Advantages, limitations, and applications, Advanced ECT like Internal Rotating Inspection System (IRIS), Phased Array Ultrasonic Technique (PAUT),Long Range Ultrasonic Testing (LRUT),Automated Ultrasonic Testing, Time of flight diffraction (ToFD) Guided wave ultrasonic testing

Reference books:

Baldev Raj, T. Jayakumar, M. Thavasimuthu, Practical Non-Destructive Testing, 3rd Ed., Narosa.

J. Prasad, C.G.K. Nair, Non-Destructive Testing and Evaluation of Materials, Tata MacGraw Hill

B. Hull, Non-Destructive Testing, Springer.

ASM Metals Handbook, Non-Destructive Evaluation and Quality Control, Vol. 17, 9th Edition

Course outcomes:

At the end of course students will be able to

CO1. Define and demonstrate basic knowledge and comparison of the NDT methods.

CO2. Select and apply suitable method for testing and evaluation

CO3. Identify application areas of the various methods and their limitations and recommendations

CO4. Analyze and evaluate results of various testing methods

CO5. Design and develop NDT methods, simulation methods and their use.

IM-5253 Surface Engineering and Coating Technology

Course content and List of books:

Module 1 **Lectures 6**

Introduction - Importance and need of surface engineering, Past, present and future status of surface engineering, Classification of surface engineering processes, Substrates and their pretreatments, Difference between diffusion coatings and overlay coatings, Coating characteristics: Coating thickness, continuity, hardness, adhesion, porosity, bond strength.

Module 2 **Lectures 10**

Overlay coatings: Process fundamentals, advantages, limitations, and applications of (a) Thermally sprayed coatings, Thermal barrier coatings, Powders for thermal spraying and Factors influencing thermal spray coatings, Applications of thermal spraying, Recent developments in thermal spraying, (b) Electrochemical coatings-Electroplating (Cu, Ni, Cr, Zn), Electro-less nickel plating and anodizing, Coating on plastics; (c) Micro arc oxidation-Basics, technology and fundamentals of micro-arc oxidation, Advantages, shortcomings and applications of micro-arc oxidation; (d) Electro-spark coating-process-Fundamentals, mechanism of coating formation, advantages and limitations, applications, Case studies.

Module 3 **Lectures 6**

Diffusion coatings: Process fundamentals, advantages, limitations, and applications of Carburizing – Overview of pack, liquid, and gas carburizing; Nitriding – Overview of gas and liquid nitriding; Carbonitriding and Nitrocarburizing; Boronizing, Aluminized coatings, Chromized and Siliconized coatings; Plasma processes - Plasma carburizing and Plasma nitriding; Plasma immersed ion implantation, Plasma enhanced chemical vapor deposition; Plasma enhanced physical vapor deposition.

Module 4 **Lectures 6**

Thermal modification processes: Different types of lasers and their applications, Laser assisted surface modification processes-Laser surface cleaning, Laser surface hardening, Laser surface cladding, Laser surface alloying.

Module 5 **Lectures 6**

Thin film coating technology: Chemical vapor deposition (CVD), Physical vapor deposition (PVD), Electron beam evaporation, Magnetron sputtering; Diamond like carbon coating technology; Sol-gel coating technologies.

Module 6 **Lectures 6**

Evaluation of coatings: Thickness, bond strength and porosity measurement, Hardness, wear and corrosion resistance.

Readings:

1. Tadeusz Burakowski and Tadeusz Wierzchon, Surface Engineering of Metals: Principles, Equipment, Technologies, CRC Press LLC, 1999

2. K. G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, New Jersey, 1998.

3. J. R. Davis, Surface Engineering for Corrosion and Wear resistance, ASM International, 2001

4. Howard E. Boyer, Case Hardening of Steel, ASM International, Metals Park, OH 44073.

5. ASM Hand Book, Surface Engineering, Volume 5, ASM Metals Park. Ohio. USA. 1994

Course Outcome

Upon completion of this class, the students will be able to:

CO1: Identify and describe wear mechanism and corrosion mechanisms, and recognize appropriate mitigation technology and methods.

CO2: Describe the surface analysis techniques used for routine investigation of surface characteristics.

CO3: Identify, compare, and contrast surface engineering processing technologies, including vacuum technology as used in many surface engineering processes.

CO4: Know the types of Pre-treatment methods to be given to surface engineering

CO5: Select the Type of Deposition and Spraying technique with respect to the application & Study of surface degradation of materials

CO6: Describe various surface coating technologies and their applications in industry

CO7: Apply measurement techniques and carry out characterization of industrial coated surfaces

CO8: Describe standard methods of testing of modified surfaces

CO9: Fundamentals of tribology and related contact mechanics and Pros and cons of different approaches in surface engineering.

IM-5254 Automotive Materials

Course content and List of books:

Module 1: Introduction to Automotive Components **Lectures 9**

Automotive Components categories, different materials used for automotive components, functionality considerations of automotive parts, factors influencing selection of materials for components. ferrous and nonferrous metals for automotive applications, Influence of material properties on functionality and forming of components, Non-metallic materials for automotive components. Thermo plastic and thermo sets usage based on the functionality requirement, Ceramic materials: Need for ceramics. Advantages and limitations of nonmetallic materials in automotive environments.

Module 2: Advanced Automotive Materials **Lectures 9**

Strengthening mechanisms and their need in automotive environment, derivation of performance index based on the functionality of the component, Ashby technique for material selection, shape factor, manufacturing feasibility, need for composites, properties of engineering composites and their limitations, significance of Polymer - Metal - Ceramic matrix composite systems, property correlation with reinforcement shape and distribution, processing and application of different composites for automotive components.

Module 3: Advanced Manufacturing Process of Automotive Components **Lectures 9**

Conventional casting and forging processes, forming technology for light weight materials, powder metallurgy, non-conventional machining technologies like Ultrasonic machining, Water jet cutting, Electrochemical processing, Laser cutting etc., joining technologies current and emerging: resistance spot welding, clinching, friction stir welding, Laser welding, Adhesive joining, structural adhesives, self piercing rivets, Thermal joining, processing of non-metallic materials for automotive components: Molding, Extrusion, Thermo forming, Foam molding and tooling, processing of ceramics like Slip casting technique, etc.

Module 4: Energy materials in Automotive Applications **Lectures 9**

Fossil fuel, solar cell, semiconductor materials, Lithium battery, nuclear material etc. solar cars, aircraft, space solar power satellites, Nanomaterials for Photovoltaic Energy Storage, Thermo-electric Devices, Hydrogen Storage, Nanogenerators, Case studies

Text books:

1. Brain Cantor, Patrick Grant, Colin Johnston, Automotive Engineering:Lightweight, Functional, and Novel Materials, Taylor& Francis, 2008

2. Hiroshi Yamagata, The science and technology of materials in automotive engines, Woodhead Publishing, 2005

3. Jason Rowe, Advanced materials in automotive engineering, Woodhead Publishing, 2012

4. Sobey, A field guide to automotive technology, Chicago Review Press,2008

5. Michael F. Ashby, “Materials Selection in Mechanical Design”, Butterworth Heinemann, 2005.

6. Daniel Yesudian C., “Materials Science and Metallurgy”, Scitech Publications (India), 2004.

7. Polmear I.J., “Light Alloys”, Arnold Publishers, 1995.

8. Swarup D. and Saxena M.N., "Elements of Metallurgy", Rastogi Publishers, Meerut, 1994.

9. Recent Trends in Nanomaterials: Synthesis and Properties (Advanced Structured Materials),

10. Zishan Husain Khan, Springer 5. Nanomaterials and Their Applications, Zishan Husain Khan, Springer.

Course Outcome

CO1: To present a problem oriented in depth knowledge of Automobile materials

CO2: To address the underlying concepts and methods behind Automobile materials

CO3: Evaluate and arrive at material properties for automotive components and select appropriate materials

IM-5255 High Temperature Materials

Course content and List of books:

Module 1 **Lectures 8**

Introduction to high temperature Materials, Factors influencing functional life of components at elevated temperature, strengthening mechanisms at high temperature, materials and process selection, materials development and design principles for elevated temperature applications.

Module 2 **Lectures 12**

Characteristics of engineering materials at high temperature, oxidation, hot corrosion, creep, thermal fatigue, erosion, aging, structural changes, material damage, crack propagation, damage mechanics, life time analysis.

Module 3 **Lectures 12**

High temperature materials- Carbon alloy steels, Stainless steels, super alloys and titanium and its alloys, ceramics, cermets, composites, Refractory metals, alloys and Structural inter-metallic and high temperature polymers.

Module 4 **Lectures 8**

Coatings: Thermal barrier coatings, Oxidation resistant coatings.

Reading:

1. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications (Engineering Materials) Springer; 1 edition (May 19, 2000)

2. J. R. Davis: ASM specialty Hand book: Heat-Resistant materials, ASM, 1997

3. Neil Birks, Gerald H. Meier, and Frederick S. Pettit, Introduction to the High Temperature Oxidation of Metals by Cambridge University Press; 2 edition (July 23, 2009)

4. Sudhansu Bose, High Temperature Coatings, Butterworth-Heinemann; 1 edition (February 6, 2007)

5. K. L. Mittal, Polyimides and Other High Temperature Polymers: Synthesis, Characterization and Applications, Brill Academic Publications, 2009

6. R.W. Evans, and B. Wilshire, Creep of metals and alloys, Institute of Metals, London, 1985.

7. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012.

Course outcomes:

After the successful completion of this course, the students would be able to

CO1: Understand the theory and principles behind mechanism of deformation by creep and fatigue at higher temperatures.

CO2: Understand the principles behind oxidation of components at higher temperatures and related calculations involved behind thickness of an oxidized layer.

CO3: Predict Life cycle of a service component under the influence of high temperature

CO4: Predict life cycle of a component under corrosive environments.

CO5: Understand mechanism of void growth leading to ductile failure.

IM-5142 Corrosion and Prevention of Metals and Alloys

Course content and List of books:

Module 1 **Lectures 10**

Importance of corrosion, Thermodynamics and Kinetics of Electrode Processes, Free energy concept, Pourbiax Diagram for Metal Water System, Applications and Limitations, Nernst's Equation, Emf Series, Galvanic Series, anodic and cathodic reactions, electrochemical cell analogy, Concept of Over-Potential, Polarization Curves, Evan's Corrosion Diagram, mixed potential theory, Kinetics Of Passivity and Transpassivity.

Module 2 **Lectures 8**

Degradation economics, types of degradation: electrochemical, high temperature corrosion and oxidation, chemical and physical ageing of plastics, degradation of reinforced concrete, biofouling, biodegradation, corrosion of ceramics.

Module 3 **Lectures 8**

Various Forms of Corrosion Such as Uniform Corrosion, Galvanic Corrosion, Crevice Corrosion, Pitting Corrosion, filliform corrosion, Intergranular Corrosion, Selective Leaching, Erosion Corrosion, Stress corrosion cracking (SCC), Environmental assisted cracking (EAC), fretting damage, Hydrogen Damage, corrosion fatigue, hydrogen embrittlement and microbes induced corrosion

.**Module 4** **Lectures 8**

laboratory assessment of corrosion: linear polarization techniques, Tafel extrapolation, oxidation, free energy- temperature diagrams, Use of ASTM standards like G-8, G-5, G-1, A262 etc. NACE standards / their equivalents, Surface Preparation, Exposure Technique salt spray, cyclic corrosion test, weatherometer, immersion test, Corrosion Rate Measurements. Few case studies.

Module 5 **Lectures 8**

Corrosion control: materials selection and design, protective coatings, inhibitors, passivators, electrical methods. Modification/Alteration of environment.

Readings

1. Myer Kutz, Handbook of Environmental Degradation of Materials, William Andrew Publishing, 2005

2. Denny A Jones, Principles and Prevention of Corrosion 2Ed., Pearson, 2014

3. R. D. Angel, Principles and Prevention of Corrosion, Narosa, 2010

4. Mars Guy Fontana: Corrosion Engineering, Tata McGraw-Hill Education, New York, 2005.

5. H.H. Uhlig, R. Winston Revie: An Introduction to Corrosion and Corrosion Engineering, 4th Ed, John Wiley & Sons, 2008.

Course Outcome

Upon completion of this class, the students will be able to:

CO1: Explain the importance of studying corrosion

CO2: Describe the thermodynamic aspects of corrosion

CO3: Describe the kinetic aspects of corrosion

CO4: Indicate the various forms of corrosion

CO5: Explain the measurement and control of corrosion.

IM-5262 Composites

Course content and List of books:

Module 1 **Lectures 6**

Introduction to composites, terminologies, schematic representations, definitions, types and characteristics of composites, matrices, and reinforcements; Classifications for the various types of composites, applications, and advantages; Fundamental concept of reinforcement; Review of current developments.

Module 2 **Lectures 6**

Constituents of Composite materials; types of fiber and matrix materials; basic mechanics of reinforcement, fiber/matrix interface, measurement of interface strength, stiffness of parallel arrays of fibers in a matrix; characterization of systems: discontinuous and particulate reinforcement, carbon fiber/epoxy, glass fiber/polyester, etc. fibers and resin materials.

Module 3 **Lectures 8**

Anisotropic elasticity; Hook's law; orthotropic materials; transverse and isotropic stiffness matrix; volume and mass fraction, rule of mixtures, critical fiber length, density, and void content; evaluation of elastic Moduli, longitudinal strength, transverse strength.

Module 4 **Lectures 8**

Matrix and reinforcement materials, polymeric matrices, metallic matrices, ceramic matrices, particulates, flakes, whiskers, fibers: glass, aramid, alumina, silicon carbide; nature and manufacture of glass, carbon, and aramid fibers; review of the principal thermosetting and thermoplastic polymer matrix systems for composites.

Module 5 **Lectures 8**

Failure analysis and design; special cases of laminates; toughening mechanisms, nature of fiber surfaces, wetting and adhesion, strength, stiffness, fracture toughness and toughening mechanism of composites, strength of unidirectional composites; failure criteria and failure modes; application of fracture mechanics to composite materials.

Module 6 **Lectures 6**

Nano-composites: synthesis and properties of nano-composites; manufacturing process (in brief); design, fabrication, and economic considerations.

Reference Books:

1. Chawla, Composite Materials Science and Engineering, Springer.

2. Hull, An Introduction to Composite Materials, Cambridge.

3. Mathews and Rawlings, Composite Materials: Engineering and Science, Chapman, and Hall.

4. Jones, R M, Mechanics of Composite Materials, Scripta Book Co.

Course Outcomes (COs)

At the end of the course, students will be able to:

CO1: Describe synthesis, processing, and properties of Fibers for composite reinforcements.

CO2: Examine bonding and properties of composite interfaces. To provide guidelines for selection of matrix materials.

CO3: Describe key processing techniques for producing metal-, ceramic-, and polymer matrix composites.

CO4: Demonstrate the relationship among synthesis, processing, and properties in composite materials.

CO5: Analyze the mechanics of the composite properties. To provide theoretical treatment of the composite properties.

IM-5263 Forging Die Design & Manufacturing

Course content and List of books:

Module 1: **Lectures 6**

Job Analysis, Steps for die design. Location of parting line, Importance of Design of flash and gutter. Determination of width and thickness.

Module 2: **Lectures 8**

Design of edger, fuller, bender, blocker, finishing impression, Reduced Roll design, Preform design. Dovetail, cross, key and tapered key. Laws governing the design of the dies of horizontal forging machine. Design of punches and heading tools for up setter (horizontal forging machine). upsetting rule, coning Tool Design Method.

Module 3: **Lectures 8**

Determination of stock size, tensile strength of material at the finishing temperature while forging. Capacity calculation of drop hammer, mechanical press, Determination of capacity of trimming press. Design of trimming and piercing tool, die clearance between punch and die. Design of stripping tool. Assembly detail for trimming.

Module 4: **Lectures 7**

Selection of the size of massive die blocks or insert dies. Production of die blocks, technical requirements for sinking, re-sinking of dies, Die sinking methods like copy-milling, EDM, ECM etc.

Module 5: **Lectures 7**

Instruction for mounting, setting and working of dies, Die material selection, Die Wear, Factors minimizing die wear , Die failure analysis, Die life improvement

Module 6: **Lectures 6**

Computer aided design of forging dies, Optimization of die design parameters, Optimum material utilization, Modeling and Simulation of forging process.

Reference Books:

1. Die Design by A. Thomas DFRA (UK)
2. Cold and Hot Forging ASM (Ohio,USA)
3. Forging Plant by A. Thomas DFRA (UK)
4. Forging Die Design by T. Altan
5. Forging Die Design and Practice by Sharan,Prasad, Saxena.
6. ASM Metals Handbook, Forming and Forging, Vol.14, ASM Internationals, Metals Park, Ohio, USA

Course outcomes:

CO1 Understand basic of Die design , development of forging drg., metal flow in closed dies

CO2 Design of flash and gutter , different preform impressions including finisher for a product

CO3 Determine size of billet, die block size, capacity of different equipments needed

CO4 Understand die manufacturing steps ,die sinking methods

CO5 Understand die setting procedure for hammer & press

CO6 Optimize die design parameters for maximum yield.

IM-5264 Advanced Powder Metallurgy

Course content and List of books:

Module 1: **Lectures 8**

Scope, advantages and limitations of powder metallurgical techniques. Powder Production:Chemical reaction and decomposition, atomization of liquid metals, electrolytic deposition and mechanical processing of solid materials.

Module 2: **Lectures 8**

Powder characteristics: Composition, structure, size, shape, surface topography, area, apparent and tap density, Flow rate, compressibility, pyrophorocity and toxicity.

Module 3: **Lectures 8**

Compaction Methods: Die, isostatic and continuous compaction. Effect of compaction variables. Pressure, speed, particle characteristics and lubrication, characteristics of compacts.

Module 4: **Lectures 8**

Sintering mechanism: Driving force, material transport mechanism, sintering variables, solid and liquid phase sintering, hot and warm pressing.

Module 5: **Lectures 8**

Production of Powder metallurgy products: Bearing, sintered carbides, magnetic materials, electrical contact materials, refractory materials and cermets and SAP.

Reference Books:

1. Randal,G., Powder Metallurgy, John Wiley
2. Metal Powder Handbook, ASM

Course Outcome (COs):

Upon completion of this class, the students will be able to:

CO1: To evaluate and propose optimum technology for preparation of powder materials.

CO2: To evaluate and evaluate influence of individual technological parameters on basic powder metallurgy operations.

CO3: To optimize material and technological parameters of production.

IM-5271 Nanostructure Materials

Course content and List of books:

Module 1: **Lectures 10**

Length scales, surface area/volume ratio of micron to nanoscale materials, Importance of Nanoscale and Technology, Top down and bottom up approaches, Classification of nanomaterials, effect of particle size on thermal properties, electrical properties, mechanical properties, magnetic properties, opticalproperties and chemical sensitivity. Examples of inspiration from the Nature and ancient history

Module 2: **Lectures 8**

Synthesis of Nanomaterials: Top-down approaches-lithography, mechanical alloying, severe plastic deformation, Bottom-up approaches-physical vapour deposition, chemical vapour deposition, molecular beam epitaxy, colloidal or wet chemical route, green chemistry route, sol-gel method, atomic layer deposition.

Module 3: **Lectures 8**

Synthesis, purification, properties and applications of carbon nanotubes (CNT). Synthesis, properties and applications of graphene. Synthesis, properties and applications of nanowires. Fabrication and properties of polymer matrix nanocomposites filled with CNT, graphene, nanowires, clay nanoparticles. Trade-off between the composites and nanocomposites.

Module 4: **Lectures 8**

Characterization of Nanomaterials: Basic principle and applications of X-ray diffraction (XRD), Optical spectroscopy, Surface area analysis (BET method), Light scattering method, Scanning electron microscope (SEM), Transmission Electron Microscope (TEM), Scanning probe microscopy- Atomic force microscope (AFM) and scanning tunneling microscope (STM), X-ray photoelectron spectroscopy.

Module 5: **Lectures 8**

Applications of nanomaterials: nanofluids, hydrogen storage, solar energy, antibacterial coating, self-cleaning coating, nanotextiles, biomedical field, water treatment, automotive sector, catalysts. Challenges of nanomaterials, Risks and toxicity from metallic and oxide nanoparticles, Recent advances in nanoscience and nanotechnology.

Readings:

1. B S Murty et. al. : Textbook of Nanoscience and Nanotechnology, Universities Press (India) Private Limited 2013.

2. Sulabha K. Kulkarni: Nanotechnology Principles and Practices, Capital Publishing Company, 2007.

3. H. Hosono, Y. Mishima, H. Takezoe, K.J.D Mackenzie: Nanomaterials- From Research to Applications, Elsevier, 2008.

4. Massimilano Di Ventra, S. Evoy, James R. Heflin Jr: Introduction to Nanoscale Science and Technology, Springer, 2009.

5. Charles P. Poole, Jr. and Frank J. Owens, Introduction to Nanotechnology, 2003, Wiley (ISBN: 978-0-471-07935-4).

Course Outcome

Upon completion of this class, the students will be able to

CO1: Explain methods of fabricating nanostructures.

CO2: Relate the unique properties of nanomaterials to the reduce dimensionality of the material.

CO3: Describe tools for characterization of nanostructures.

CO4: Discuss applications of nanomaterials and implication of health and safety related to nanomaterials.

IM-5272 Additive Manufacturing

Course content and List of books:

Module 1: **Lectures 6**

Introduction: Overview, Basic principle need and advantages of additive manufacturing, Procedure of product development in additive manufacturing, Classification of additive manufacturing processes, Materials used in additive manufacturing, Challenges in Additive Manufacturing.

Module 2: **Lectures 8**

Generic AM process: CAD, Conversion of STL, Transfer to AM machine and STL file manipulation, machine setup, Build, Removal, Distinction between AM and CNC machining, Reverse engineering

Module 3: **Lectures 14**

Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing (LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Material Jetting, Binder jetting

Powder bed Fusion processes: Selective laser sintering (SLS), Laser engineered net shaping (LENS), Selective laser melting (SLM), Electron beam melting (EBM), Materials, Powder fusion mechanisms (Solid-state sintering, chemically induced sintering, liquid phase sintering, Full melting), powder handling challenges, powder recycling, defects

Direct energy deposition processes: DED process description, powder feeding, wire feeding, laser and electron based deposition processes

Module 4: : Lectures 10

Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, Brief information on characterization techniques used in additive manufacturing, Applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Module 5: : Lectures 4

Future scope in Additive Manufacturing: Scope of AM in various fields. Its importance and applications.

Readings

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.

2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014

4. A. Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.

5. L.W. Liou, F.W. Liou: Rapid Prototyping and Engineering applications: A tool box for prototype development, CRC Press, 2007.

6. A.K. Kamrani, E.A. Nasr: Rapid Prototyping- Theory and Practice, Springer, 2006.

7. P.D. Hilton, P.F. Jacobs: Rapid Tooling- Technologies and Industrial Applications, CRC Press, 2000.

8. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

9. D.T. Pham, S.S. Dimov: Rapid Manufacturing- The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer, 2001.

Course Outcome

Upon completion of this class, the students will be able to:

CO1: Understand the fundamentals of Additive Manufacturing Technologies for engineering applications.

CO2: Understand the methodology to manufacture the products using SLA and SGC technologies and study their applications , advantages and case studies

CO3: Understand the methodology to manufacture the products using LOM and FDM technologies and study their applications , advantages and case studies

CO4: Understand the methodology to manufacture the products using SLS and 3D Printing technologies and study their applications , advantages and case studies

<u>IM-5273 Industrial Engineering and Operation Management</u>

Course content and List of books:

Module 1: **Lectures 8**

Work Study Fundamentals:

Productivity, Definition and Scope of Motion and Time Study, History of Motion and Time Study, Work Methods Design – the Broad View and Developing a Better Method, Reducing Work Content and Ineffective Time, Human Factors in the Application of Work Study. Work Measurement: Its Purposes and Uses, Basic Procedure, Techniques of Work Measurement – Work Sampling, Stop-Watch Time Study, Concepts of Rating and Allowances, Setting Standard Times for Jobs, Standard Data, Predetermined Time Standards : Work-Factor, and Methods-Time Measurement.

Module 2: **Lectures 10**

Operations Research:

Linear Programming: Two variable LP model, graphical method and simplex method, revised simplex method, special cases in simplex method application, comprehensive problems; 2. Duality and Sensitivity Analysis: Primal dual relationship and economic interpretation of duality, dual simplex method, sensitivity analysis, comprehensive problems; 3. Transportation Model and its Variants: Transportation algorithm, assignment model-Hungarian method, transshipment model, comprehensive problems; 4. Integer Programming: Branch and bound algorithm, cutting plane algorithm, comprehensive problems; 5. Introduction to Goal Programming: comprehensive problems; 6. Dynamic Programming: Forward and backward recursion-stagecoach problem, knapsack model, comprehensive problems; 7. Classical Optimization Theory: Unconstrained and constrained problem, comprehensive problems.

Module 3: **Lectures 8**

Function of management:

Planning-strategic, tactical and operation planning, short-medium-longterm planning; organizing-different organization structure, peters principles ;staffing-delegation of authority and power roles and responsibilities; leading-kinds of leaderships, motivation theories, Parkinson's law; control-fit forward and fit back control; 3. Basics of productivity and performance management: productivity cycle, performance management, classification of productivity and performance measurement tools and techniques NPMMP including evaluation norms and systems in manufacturing and service organization, productivity planning application, productivity performance-measurement techniques ,NC, surrogate measurement technique;

Module 4: **Lectures 8**

Engineering Economy and Costing

Time value of money: Series of cash flows, uniform series of cash flows, uniform gradient series formula. • Worth of investments: Present worth method (PW), annual worth method (AW), future worth method (FW), internal rate of return method. • Depreciation: Sum of the years' digits depreciation, MACRS depreciation method. • Profitability of investments • Inflation • Break-Even and sensitivity analysis • Uncertainty and risk analysis • Benefit-cost analysis

Module 5: **Lectures 8**

Statistical Process Control (SPC):

(a) Control Chart Principles: Causes of Variation, Statistical Aspects of Control Charting, Concept of Rational Subgrouping, Detecting Patterns on Control Charts (b) Control Charts for Attributes: p, np, c, u, and U charts (c) Control Charts for Variables: R, X, S, and X charts (d) Special Control Charts: Cusum, Trend, Modified and Acceptance, Moving Average, Geometric Moving Average, and Multivariate Control Charts. (e) Specifications and Tolerances: Natural Tolerance Limits and Specification Limits, Process Capability Ratios, and Process Capability Analysis

Readings:

1. International Labor Organization, Introduction to Work Study.
2. Sanders, M. S. and McCormick, E. J., Human Factors in Engineering and Design, McGraw-Hill.
3. Ravindran, A., Philips, D.T., and Solberg, J.J., Operations research, John Wiley and Sons.
4. Buffa, E S, Modern Production Management, Wiley Eastern.
5. Scott Sink, D, Productivity Management: Planning, Measurement and Evaluation Control and Improvement, John Wiley.
6. Taylor, G A, Managerial and Engineering Economy, Van Nostrand Reinhold Inc.
7. Sullivan, W G, Bontadelli, J A and Wicks, E M, Engineering Economy, Pearson Education Asia.
8. Duncan, A J, Quality Control and Industrial Statistics, Richard D. Irwin.
9. Mitra, A. Fundamentals of Quality Control and Improvement, Prentice-Hall

Course Outcomes (COs)

CO1: To apply the basic concepts and its applications, method and time study techniques, for work systems and product design improvement

CO2: learn the techniques of operations research as they are applied in manufacturing and service organization for improve performance and design of optimized systems/sub-systems.

CO3: To apply the fundamentals of management concept with its principles and practice as well as tools and techniques related to productivity engineering and management

CO4: To use the statistical process control techniques, sampling, reliability, product and process design techniques in manufacturing and service systems for quality control and improvement.

IM-5274 Deformation Behavior of Materials

Course content and List of books:

Module 1 **Lectures 8**

Strength of Materials: Basic assumptions, elastic and plastic behavior, stress- strain relationship for elastic behavior, elements of plastic deformation of metallic materials, Mohr's circle, yielding theories.

Module 2 **Lectures 8**

Theory of plasticity: Dislocation theory, properties of dislocations, stress fields around dislocations, application of dislocation theory to work hardening, solid solution strengthening, grain boundary strengthening, dispersion hardening.

Module 3 **Lectures 8**

Ductile and brittle fracture: Charpy and Izod testing, Significance of DBTT, ECT, NDT and FATT; Elements of fractography; Griffith theory, LEFM- COD and J integral, determination of KIC, COD and J integral.

Module 4 **Lectures 8**

Fatigue failure: Initiation and propagation of Fatigue cracks, factor affecting fatigue strength and methods of improving fatigue behavior, testing analysis of fatigue data, mechanism of fatigue crack propagation, Corrosion fatigue.

Module 5 **Lectures 8**

Creep failure: Creep mechanism, creep curve, variables affecting creep, accelerated creep testing, development of creep resisting alloys, Larsen- Miller parameter, Manson Hafred parameter.

Reference Books:

1. Dieter, G. E., Mechanical metallurgy, McGraw Hill.

2. Hertzberg, R.W., Deformation and fracture mechanics of engineering materials, John Wiley

3. Hull, D., Introductions to dislocations, Pergamon.

4. Garofalo, F., Fundamentals of creep and creep rupture in metals, McMillan.

5. Meyers, M. A., and Chawla, K.K., Mechanical behavior of materials, Prentice Hall

Course Outcomes (COs)

CO1: In this post graduate course, the mechanical behavior of materials has to be taught where the materials' responses to tensile or compressive loads are to be studied, with their industrial and engineering applications.

CO2: To study how an alternating load play a role for a catastrophic failure of an engineering structural part. Quantification of the life in such environment of a structural part.

CO3: To understand material's behavior when it is exposed to high temperature and how the temperature activated deformation process leads to failure of a part.

CO4: To study, determine and quantify how existence of internal flaw (cracks, voids etc) leads to material failure.

IM-5211 Metal Casting and Forming Technology Laboratory

List of Experiments: [Any 08 Experiments]

1. To study the different types of foundry tools and equipments utilized during casting.
2. Experiment on melting in Muffle or Induction furnace and produce a casting from the molten metal

3. Demonstrate Pattern and core making, preparation of core sand and it's testing e.g. Hardness, Flow ability, Mould ability, etc.
4. To study the shrinkage behavior during permanent mold casting
5. Design the manufacturing process flowchart and process parameters for a casting suitable for a particular application.
6. To do the different types of press working operations in the piece of given sheet metal.
7. Perform Erichsen cupping test to determine the ductility of metal sheets and strips (ASTM E643 standard).
8. Study of variation in material flow lines or microstructurr with respect to various forging technique used for forming.
9. Correlate metallurgical factors and its influence on mechanical properties of a ferrous or nonferrous metal subjected to variation in process parameters in a forging process.
10. To study the property changes of ferrous and non-ferrous metals during cold and hot rolling

Course Outcomes (COs)

At the end of course students will be able to

CO1: develop in depth understanding of casting technology

CO2: Correlate metallurgical factors and its influence on mechanical properties of formed products

IM-5212 Modelling, Simulation and Computer Applications In Metallurgy Laboratory

List of Experiments: [Any 08 Experiments]

1. Origin curve fitting, smoothening for a given data set

2. Residual stress calculations using XRD software like Topas/Xscore

3. Heat transfer calculation using COMSOL for a given problem

4. Phase diagram preparation of given Al and Mg alloy using Factasge or thermocalc

5. Phase diagram calculation using CALPH AD and comparison with experiment 4

6. Stress localization calculation in alpha and beta phase using OIM software for 5% and 10% strained Ti-alloy

7. Designing engine parts using sand casting, investment casting and permanent mold casting using click 2 cast

8. Hydrogen/oxygen diffusion flux calculation in pure Al using FEM method

9. Rules generalization for given set of data using R software

10. Stress calculation in structural part of automotive using Ansys/Abascus

Course Outcomes (COs)

At the end of course students will be able to

CO1: have hands-on experience on software and guidance to solve practical problems

CO2: give overview of different software to give idea of choosing right software for solving problem.