

Metallurgical Engineering syllabus

Subjects for Pre-PhD

Paper-1

1. Advances in Metal Casting
2. Advances in Metal Forming
3. Advances in Welding
4. Advances in Heat Treatment
5. Phase transformations

Paper-2

1. Powder Metallurgy
2. Failure Analysis
3. Corrosion Engineering
4. Composite Materials
5. Nano Technology

ADVANCES IN METAL CASTING

UNIT-I

PATTERN PREPARATION AND MOULDING

Introduction to foundry operations, moulding practice, ingredients of moulding sand and core sand, Testing of Moulding sands. Sand preparation, Sand moulding: green sand moulding, dry sand moulding, skin dry sand moulding, core sand moulding, loam moulding, fluid sand process, shell moulding, pit and floor moulding, carbon-di-oxide process.

UNIT-II

MELTING PRACTICE

Melting practice and special precautions for steels, alloy steels, cast irons, aluminium alloys, copper alloys and magnesium alloys, safety considerations, fluxing, degassing and inoculation

UNIT-III

CASTING TECHNIQUES

Sand casting, permanent mould casting, die casting, centrifugal casting, plaster mould casting, investment casting, continuous casting, squeeze casting, full mould process.

UNIT-IV

DESIGN OF CASTINGS AND FOUNDRY METALLURGY

Elements of gating system, types, design of gating system with examples, functions of risers, types of risers, Chvorinov's rule, design and positioning of riser with examples, directional solidification, use of chills, exothermic compounds etc., riser efficiency, yield calculations. Concepts of pouring, solidification and shrinkage, inoculation and modification of cast irons and Al-Si systems.

UNIT-V

INSPECTION AND AUTOMATION

Cleaning and repair of castings. Casting defects and remedies. Heat treatment of castings. Inspection of casting. Principles of mechanisation, automation and foundry layout. Pollution control and safety considerations in foundries. Functional design, simplification of foundry practices, metallurgical design

TEXT BOOKS

1. Heine. R.W., Loper. C.R., Rosenthal, P.C. "Principles of Metal Casting", Tata McGraw-Hill Publishing Co., Ltd., New Delhi, 1995.
2. Jain.P.L., "Principles of Foundry Technology", Tata McGraw-Hill Publishing Co., Ltd., New Delhi, 1995.

REFERENCES

1. Ramana Rao.T.V. "Metal Casting Principles and Practice", New Age Pub. Co., New Delhi, 1996.
2. Beeley.P.R., "Foundry Technology", Butterworths, London, 1982.
3. Srinivasan.N.K, "Foundry Engineering", Khanna Tech Publications, New Delhi, 1994.
4. ASM Metals hand Book. Vol. 15. "Casting", ASM International, 10th Edition, 1991.

ADVANCES IN METAL FORMING

UNIT I:

Description of stress at a point. State of stress in two dimensions. Mohr's circle of stress in two dimensions, state of stress in three dimensions. Mohr's circle of stress in three dimensions. Description of strain at point. The flow curve, True stress and true strain. Von Mises distortion energy criterion, maximum shear stress or Tresca criterion. Octahedral shear stress and shear strain. Basics of the theories of plasticity.

UNIT II

Classification of forming processes, Mechanics of metal working for slab method and uniform deformation energy method. Cold working, Recovery, recrystallisation and grain growth, hot working, Strain-Rate effects, Work of plastic deformation.

UNIT III

Classification of forging processes, forging equipment. Forging in plane strain. Open-die forging, closed-die forging, Forging of a cylinder in plane-strain. Forging defects, powder metallurgy forging.

UNIT IV

Classification of rolling process, rolling mills. Hot rolling, cold rolling, rolling of bars and shapes, forging and geometrical relationships in rolling. rolling variables, problems and defects in rolled products. Theories of hot rolling, torque and horsepower, theories of cold rolling, torque and horsepower.

UNIT V

Classification of extrusion processes, Determination of ideal force and frictional force in direct extrusion, Extrusion variables, extrusion defects, Extrusion of tubing and production of seamless pipe and tubing. Deep drawing, defects in deep drawing, Rod and wire drawing, tube drawing processes, residual stresses in rod, wire and tubes.

TEXT BOOK:

1. Mechanical Metallurgy by GE Dieter (3rd edition)

REFERENCES:

1. Kurt Lange "Handbook of Metal Forming", Society of Manufacturing Engineers. Michigan, USA, 1988
2. Avitzur, "Metal Forming - Processes and Analysis", Tata McGraw-Hill Co., New Delhi,
3. ASM Metals Handbook. Vol.14, "Forming and Forging", Metals Park, Ohio, USA, 1990.
4. Taylor Altan, Soo I.K. Oh, Harold.L.Gegel. "Metal Forming: Fundamentals and Applications", ASM, Metals Park, Ohio, USA, 1983.

ADVANCES IN WELDING

UNIT-I

GAS AND ARC WELDING PROCESSES

Classification of welding processes- heat sources and shielding methods- fusion welding processes, oxy-acetylene welding, arc welding-manual, submerged arc welding, gas tungsten arc and gas metal arc welding, electro slag and electro gas welding.

UNIT - II

PRESSURE WELDING PROCESSES

Cold and hot pressure welding, friction, friction stir welding, ultrasonic, induction pressure, explosive and diffusion welding.

UNIT - III

SPECIAL WELDING PROCESSES

Principle, equipment, process variables, merits, limitations and applications of Electron beam, plasma arc and laser beam welding processes.

UNIT - IV

PERIPHERAL JOINING AND CUTTING PROCESSES

Principle, techniques, joint design, materials, merits, limitations and applications of Brazing, soldering and cutting processes. Hard facing techniques.

UNIT-V

WELDING METALLURGY

Weld thermal cycles and their effects, structural changes in different materials, effects of pre and post heat treatments, concept of weldability and its assessment, Welding of mild, high tensile and stainless steels, cast irons and non-ferrous alloys based on aluminium, titanium and copper. Defects in welds, their causes and remedies.

TEXT BOOKS

- 1 Parmar, R.S., "Welding Processes And Technology", 2nd edn. Khanna Pub., New Delhi, 2001
- 2 Srinivasan.N.K.. "Welding Technology", Khanna Publications, Delhi, 1995.
- 3 Nadkarni.S V. "Modern Arc Welding Technology", Oxford & IBH, New Delhi, 1988.

REFERENCES

1. ASM Metals Handbook. Vol.6. "Welding Brazing & Soldering", ASM International, Metals Park, Ohio, USA, 1993.
2. AWS Welding Handbooks, AWS, New York, 1995
3. Davies-A C. "Welding", 10th edition, Cambridge University Press, UK, 1996.
4. Howard B Cary., "Modern Welding Technology", 4th edn., Prentice Hall, New Jersey, USA, 1997.
5. Lancaster.J.F., "Metallurgy of Welding", George Allen Co, Boston, 1980.

ADVANCES IN HEAT TREATMENT

UNIT-I

PRINCIPLES OF HEAT TREATMENT: Austenitic Transformation, Pearlitic Transformation, Bainitic Transformation, Martensitic Transformation, Annealing, Normalizing, Hardening, mechanism of heat removal during quenching, quenching media, size and mass effect, hardenability, tempering, austempering, manufacturing, deep freezing.

UNIT-II

Surface heat treatment, carburizing, cyaniding, flame and induction hardening, residual stresses, deep freezing, thermo mechanical treatments: HTMT, LTMT, Ausforming, Isoforming, Cryoforming.

UNIT-III

Effect of alloying elements on ferrite, cementite, Fe-Fe₃C system, tempering and TTT Curves.

UNIT-IV

Heat treatment of Structural and constructional steels, tool and die steels, Corrosion and heat resistant steels, Hadfield steels, Heat treatment of cast irons.

UNIT-V

Precipitation hardening, aging treatment, study of copper and its alloys, aluminum and its alloys, nickel and its alloys.

TEXT BOOK:

1. Heat Treatment Principle and Techniques-Rajan & Sharma

REFERENCES:

1. Physical Metallurgy Lakhtin-Mir Publishers
2. Physical Metallurgy - Clark and Varney
3. Physical Metallurgy Principles - Reed Hill
4. Physical metallurgy-Ragavan
5. Heat Treatment of metals-Zakharv-Mir Publishers

PHASE TRANSFORMATIONS

UNIT-I

DIFFUSION CONTROLLED PHASE TRANSFORMATION

Nucleation and growth - Types of nucleation - Concept of free energy during solidification - Thermodynamics of homogeneous nucleation - critical nucleus size and critical free energy change - Constitutional supercooling - Extension to heterogeneous nucleation - Nucleation rate and Growth rate - Overall Transformation rate. Concept of Activation energy - Arrhenius equation - Johnson Mehl - Avrami equation. Pearlritic transformations.

UNIT-II

DIFFUSIONLESS TRANSFORMATIONS

Martensite transformation - Definition - characteristic features of Martensitic transformation in steels - Morphology of Martensite - lath and acicular Martensite - Crystallography of Martensitic transformation - Martensite in Non-Ferrous systems - Thermo Elastic Martensite - Shape Memory effect - Examples and applications of shape memory alloys.

UNIT-III

STRENGTHENING MECHANISMS

Elementary discussion of cold working, grain size strengthening. Solid solution strengthening. martensitic strengthening, dispersion strengthening, fibre strengthening, examples of above strengthening mechanisms from ferrous and non-ferrous systems, simple problems. Yield point phenomenon, strain aging and dynamic strain aging

UNIT-IV

PRECIPITATION HARDENING

Precipitation from solid solutions, thermodynamic considerations, structure and property during ageing, sequence of ageing, formation of G-P zones and intermediate precipitates, theories of precipitation hardening, effect of time, temperature and alloy compositions, precipitation free zones, crystallographic aspects of transformation, coarsening kinetics.

UNIT-V

ANNEALING

Cold working and hot working. Recovery - polygonization and dislocation movements in polygonization. Recrystallisation - effect of time, temperature, strain and other variables, mechanism of nucleation and growth. Grain growth – Grain growth law, geometrical collisions, preferred orientation, secondary recrystallisation.

TEXT BOOKS

1. Raghavan.V., "Phase Transformations", Prentice - Hall of India, New Delhi, 1990.
2. Dieter, G.E., "Mechanical Metallurgy", McGraw-Hill, New York, 1995.

REFERENCES

1. Reed Hill. R.E. "Physical Metallurgy Principles", Affiliated East West Press. New Delhi. 1992.
2. Thomas H Courtney, "Mechanical Behaviour of Materials", McGraw-Hill Co., NY. 1990.
3. Romesh C. Sharma, "Phase transformation in Materials", CBS Publishers & Distributors, New Delhi, 2002.

POWDER METALLURGY

UNIT – I

Characterization and production of powders: General characteristics of metal powders, particle shape flow rate, apparent density, and specific surface area, particle size distribution. Different methods of production of metal powders: influence of manufacturing process on powder characteristics.

UNIT – II

Consolidation of Metal Powders by Compaction: Theory of consolidation: Pressure transmission in powders; compressibility and compactibility of powders; Green strength; Hot isostatic pressing; Powder rolling.

UNIT – III

Consolidation of Metal Powders by Sintering: Mechanisms of Sintering; Factors affecting sintering; Activated sintering; Liquid phase sintering; Sintering atmospheres; Properties of sintered parts.

UNIT – IV

Applications: Porous parts: Self-lubricating bearings, filters: Dispersion strengthened materials: Cu / Al₂O₃, Sintered Aluminum Powder.

UNIT – V

Electrical and Magnetic materials, Tungsten lamp filaments, electrical contacts, welding electrodes. Soft magnetic materials (Fe, Fe-N); Permanent magnets (Alnico, SmCo₅), Cemented carbides; Cermets.

TEXT BOOK:

Powder Metallurgy: Anish Upadhyaya and GS Upadhyaya- University Press

REFERENCES:

1. Powder metallurgy – A.K. Sinha
2. Introduction to powder metallurgy – J.S. Hirshhorn
3. Treatise on Powder metallurgy – C. Goetzel Vol I & II
4. Powder Metallurgy principles – F.V. Lenel

FAILURE ANALYSIS

UNIT-I

SOURCES OF FAILURES

Deficiencies in Design, Material, Processing, Service and Maintenance. Stages of Failure Analysis, classification and Identification of Various Types of Fracture - Overview of Fracture Mechanics Concepts, Ductile and Brittle Fracture, Fracture Origin, Initiators, characteristics of Ductile and Brittle Fracture.

UNIT-II

FATIGUE AND CREEP FAILURES

General Concepts, Fracture Characteristics Revealed By Microscopy, Factors Affecting Fatigue Life Some Case Studies of Fatigue Failures. Creep, Stress Rupture, Elevated Temperature Fatigue, Metallurgical Instabilities, Environmental Induced Failure, Elevated Temperature Effects on Certain Gas Turbine Components And Petroleum Refinery Components.

UNIT-III

WEAR AND CORROSION FAILURES

Types of Wear, Role of Friction in Wear, Lubricated and Non-Lubricated Wear, Analyzing Wear Failure. Corrosion Failures- Factors Influencing Corrosion Failures, Analysis of Corrosion Failures, overview of Various types of Corrosion Stress Corrosion Cracking, Sources, characteristics of Stress Corrosion Cracking. Procedure for Analyzing Stress Corrosion Cracking, various Types of Hydrogen Damage Failures.

UNIT-IV

FAILURE OF FORGING, CASTING AND WELDMENTS

Causes of Failure in Forging like material characteristics, Deficiencies in design, Improper Processing / Fabrication or Deterioration resulting from service conditions, Failure of Iron and Steel Castings, effect of Surface Discontinuities, Internal Discontinuities, Microstructure, Improper Composition, Improper Heat Treatment, Stress Concentration and Service Conditions. Failure of Weldments - Reasons for Failure procedure for Weld Failure Analysis.

UNIT-V

RELIABILITY

Reliability Concept and Hazard Function, Life Prediction, Condition Monitoring, Application of Poisson. Exponential and Weibull Distribution for Reliability, Bath Rub Curve, Parallel and Series System, Mean Time Between Failures and Life Testing.

TEXT BOOKS

1. ASM Metals Handbook "Failure Analysis and Prevention", ASM Metals Park. Ohio, Vol.10, 10th Edition, 1995.
2. Colangelo.V.J. and Heiser.F.A., "Analysis of Metallurgical Failures", John Wiley and Sons Inc. New York, USA, 1974.

REFERENCES

1. Charlie R Brooks, Ashok Choudhury "Metallurgical Failure Analysis", McGraw -Hill Publishing Co. USA, 1993.
2. Das.A K "Metallurgy of Failure Analysis", Tata McGraw-Hill Publishing Co., New Delhi, 1996.

CORROSION ENGINEERING

UNIT-I

CORROSION PRINCIPLES

Electrochemical and thermodynamic principles, electrode potential of metals, EMF and galvanic series, merits and demerits, Pourbaix diagram and its importance to iron, aluminium and magnesium metals, corrosion rate expressions. Exchange current density, polarization - concentration, activation and resistance, Tafel equation, passivity, electrochemical behaviour of active-passive metals, factors governing metals exhibiting passivity, mixed potential theory and its application.

UNIT - II

FORMS OF CORROSION

Atmospheric, galvanic, crevice, pitting, stress corrosion cracking, intergranular corrosion, corrosion fatigue, hydrogen damage, cavitation, fretting corrosion and high temperature oxidation-description, causes and remedial measures.

UNIT - III

CORROSION TESTING

Purpose of testing, laboratory, semi-plant and field tests, susceptibility tests of IGC, stress corrosion cracking and pitting, sequential procedure for laboratory and on site corrosion investigations, ASTM standards for corrosion testing; polarization methods to measure corrosion rate.

UNIT - IV

CORROSION PREVENTION

Corrosion prevention by design improvements, anodic and cathodic protection, metallic, non-metallic and inorganic coatings, mechanical and chemical methods and various corrosion inhibitors

UNIT-V

CORROSION IN INDUSTRIES

Corrosion in fossil fuel power plants, automotive industry, chemical processing industries, corrosion in petroleum production operations and refining, corrosion of pipelines.

TEXT BOOKS

1. Denny A. Jones, "Principles and Prevention of Corrosion", 2nd edition, Prentice Hall, USA, 1996.
2. Fontana, M.G., Greene, N.D., "Corrosion Engineering", 2nd edition, McGraw-Hill, USA, 1983

REFERENCES

1. Raj Narayan, "An Introduction to Metallic Corrosion and its Prevention", 1st edition, Oxford & IBH, New Delhi, 1983
2. ASM Metals Handbook, Vol. 13, "Corrosion", Metals Park, Ohio, USA, 1994.
3. Uhlig Hebert H, "Corrosion and Corrosion Control", 2nd edition, John Wiley, USA 1971.

COMPOSITE MATERIALS

UNIT-I

Classification of composite materials based on structure-based on matrix, applications of composites-functional requirements of reinforcement and matrix.

UNIT-II

Fibers: Preparation, properties and applications of glass fibers, carbon fibers, Kevlar fibers and metal fibers-properties and application of whiskers, particle reinforcements.

UNIT-III

Manufacturing of advanced composites: Polymer matrix composites: Preparation of Moulding compounds and – hand lay up method – Autoclave method - Filament winding method - compression moulding – Reaction injection moulding.

UNIT-IV

Manufacturing of Metal Matrix Composites: Casting-Solid state diffusion technique. Cladding – Hot isostatic pressing. Manufacturing of Ceramic Matrix Composites: Liquid Metal infiltration-Liquid phase sintering, Manufacturing of Carbon – Carbon composites: Knitting, Braiding, Weaving

UNIT-V

Response of Composites to Stress: (a) Iso strain condition (b) Iso Stress condition (c) Load friction shared by the fibers

Text Books:

1. Material Sciences and Technology – Vol 13 – Composites by Cahn – VCH, West Germany
2. Composite Materials-K.K.Chawla

Reference:

1. Hand Book of Composite Materials-ed-Lubin

NANOTECHNOLOGY

UNIT-I

General Introduction: Basics of Quantum Mechanics, Harmonic oscillator, magnetic Phenomena, band structure in solids, Mossbauer and Spectroscopy, optical phenomena bonding in solids, Anisotropy.

UNIT-II

Silicon Carbide: Application of Silicon carbide, nano materials preparation, Sintering of SiC, X-ray Diffraction data, electron microscopy sintering of nano particles,

Nano particles of Alumina and Zirconia: Nano materials preparation, Characterization, Wear materials and nano composites,

UNIT-III

Mechanical properties: Strength of nano crystalline SiC, Preparation for strength measurements, Mechanical properties, Magnetic properties,

Unit -IV

Electrical properties: Switching glasses with nanoparticles, Electronic conduction with nano particles **Optical properties:** Optical properties, special properties and the coloured glasses

UNIT-V

Process of synthesis of nano powders, Electro deposition, Important nano materials

UNIT-VI:

Investigating and manipulating materials in the nanoscale: Electron microscopies, scanning probe microscopies, optical microscopies for nano science and technology, X-ray diffraction.

UNIT-VII

Nano-biology : Interaction between biomolecules and nanoparticle surface, Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies, Application of nano in biology, nanoprobe for Analytical Applications-A new Methodology in medical diagnostics and Biotechnology, Current status of nano Biotechnology, Future perspectives of Nanobiology, Nanosensors.

UNIT-VIII

Nano-medicines : Developing of Nanomedicines Nanosystems in use, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials for used in Diagnostics and Therapeutic applications, Molecular Nanomechanics, Molecular devices, Nanotribology, studying tribology at nanoscale, Nanotribology applications.

TEXT BOOKS:

1. Nano Materials- A.K.Bandyopadhyay/ New Age Publishers.
2. Nano Essentials- T.Pradeep/TMH