SEMESTER I

15YN01 STATISTICS, QUALITY CONTROL AND RELIABILITY ENGINEERING

2 2 0 3

SAMPLING CONCEPTS: Lot-by-Lot acceptance sampling for attributes – acceptance sampling problem, single sampling plans for attributes, double, multiple and sequential sampling plan, chain sampling, continuous sampling, skip-lot sampling plans. (5+5)

ONE FACTOR EXPERIMENTS: Analysis of variance technique – strategy of experimental design, one-way analysis of variance, completely randomized design, randomized complete block design. (3+3)

STATISTICAL QUALITY CONTROL: Methods and philosophy of statistical process control – Introduction – chance and assignable causes of quality variation, statistical basis of control charts, control charts for variables, control charts for attributes. (4+4)

RELIABILITY: Definition of reliability – reliability vs quality, the failure distribution, the reliability function, mean time to failure, Hazard rate function, bathtub curve, conditional reliability - constant failure rate model - time-dependent failure models- exponential, Weibull and normal distribution. (3+3)

RELIABILITY OF SYSTEMS AND PHYSICAL RELIABILITY MODELS: Serial configuration, parallel configuration, combined series parallel systems, system structure function, minimal cuts and minimal paths – load sharing systems – standby systems – degraded systems, three state devices – physical reliability models - covariate models, static models , dynamic models, physics of failure models. (5+5)

DESIGN FOR RELIABILITY, MAINTAINABILITY AND AVAILABILITY: Reliability specification and system measurements - reliability allocation - design methods – failure analysis – system safety and fault tree analysis – analysis of down time – the repair time distribution, reliability under preventive maintenance, maintenance requirements, availability concepts and definitions, system availability. (6+6)

THE ANALYSIS OF FAILURE DATA AND RELIABILITY TESTING: Data collection – empirical methods, ungrouped and grouped complete data, ungrouped and grouped censored data – static life estimation – test time calculation, burn in testing, acceptance testing. (4+4)

Total L: 30 + T: 30 = 60

REFERENCES:

1. Ronald E Walpole, Raymond H Myers, Sharon L Myers and Keying Ye, “Probability and Statistics for Engineers and Scientists”, Pearson Education, New Delhi, 2007.
2. Douglas C Montgomery, “Introduction to Statistical Quality Control”, John Wiley & Sons, New York, 2009.
3. Dale H Besterfield, “Quality Control”, Pearson Education, New Delhi, 2008.
4. Charles E Ebeling, “An Introduction to Reliability and Maintainability Engineering”, Tata McGraw-Hill, New Delhi, 2009.
5. Trivedi K S, “Probability and Statistics with Reliability, Queueing and Computer Science Applications”, Prentice Hall, New Delhi, 2008.
6. Amitava Mitra, “Fundamentals of Quality Control and Improvement”, John Wiley and Sons, New Jersey, 2008.

15YN02 ENGINEERING PHYSICAL METALLURGY

2 2 0 3

CRYSTALLOGRAPHY AND CRYSTAL DEFECTS: Crystal systems-Detailed discussion of common crystal structures in metals and alloys. Crystal defects: Classification-Point, line, area and volume defects. Voids-types and location in BCC, FCC and HCP structures- influence of defects on properties. Introduction to nanostructures, metallic glasses, Quasi-crystals. (8+3)

ALLOYING THEORY AND PHASE DIAGRAMS: Types of solid solutions and compounds-Hume-Rothery rules for formation of substitutional solid solutions-properties of solid solutions. Essential principles of solidification. Determination and uses of phase diagrams. Types of phase reactions with examples. Phase rule and its application to phase diagrams-Lever rule. Detailed discussion of Fe-C equilibrium diagram. Concept of ternary phase diagrams-Exercise problems. (12+3)

DIFFUSION IN SOLIDS: Diffusion-Concept of activation energy- Mechanisms of diffusion - Fick's 1^{st} Law of diffusion-Diffusion coefficient-factors affecting diffusion coefficient-Fick's 2^{nd} Law of diffusions-inter diffusion-Kirkendall effect-Modes of diffusion (surface, volume and grain boundary)- Industrial applications-Numerical problems. (5+3)

THEORY OF PHASE TRANSFORMATIONS: Nucleation and growth-homogeneous and heterogeneous nucleation-Isothermal transformations-TTT diagrams. Diffusionless transformation- Martensitic transformation in ferrous and non-ferrous metals-Shape Memory Effect and its applications Spinoidal decomposition. (10+3)

COLD WORKING AND HOTWORKING: Structure and properties of cold worked metals-Annealing-recovery, recrystallisation and grain growth, comparison of cold working and hot working. (5+2)

STRENGTHENING MECHANISMS: Cold working, Grain size control, precipitation strengthening, dispersion strengthening, particulate and fiber strengthening, texture strengthening. (5+1)

Total L: 45+T: 15 = 60

REFERENCES:

1. Van Vlack L H, “Elements of Material Science and Engineering”, Addison Wesley Publication, New York, 1975.
2. James F Shackle Ford, “Introduction to Material Science for Engineers”, Macmillan, 1992.
3. Willaim F Smith, “Foundations of Materials Science & Engineering”, Mc Graw Hill, 1993.
4. Anderson, Leaver J C, Leaver K D and Rawlings R D, “Material Science for Engineers”, Chapman and Hall, London, 2003.
5. Donald R Askeland, “The Science and Engineering of Materials”, Thomson Brooks / Cole, 2003.
6. William D Callister, “Materials Science Engineering- An Introduction”, John Wiley & Sons, 2003.
7. Ragavan V “Material Science & Engineering-A First Course”, Prentice Hall International, New York, 2004.
8. Avner S H, “An Introduction to Physical Metallurgy”, McGraw Hill Book Co., New York, 2004.
9. Vijendra singh, “Physical Metallurgy”, Standard Publishers distributors, 2005.

15YN03 FOUNDRYTECHNOLOGY

3 0 0 3

INTRODUCTION: Comparison of Solidification route with other manufacturing routes. (2)

PATTERNS: Types, design of patterns, Allowances material selection, manufacture of patterns. (4)

MOULDIING AND CASTING PROCESSES: Classification of moulding processes, mould materials, basic requirement of mould sands, preparation of mould sands, bonds formed in moulding aggregates, sand testing, green sand moulds, dry sand moulding, loam moulding, Co_2 molds. Resin binder processes, plaster moulding processes, ceramic moulding processes, investment casting processes, graphite moulding processes, permanent mould casting processes, die casting processes, types of centrifugal casting processes, continuous casting processes, new casting processes-Squeeze casting, semi solid metal casting, directional solidification processes, CLA process, Thixocasting and Rheocasting processes. (8)

MELTING: Construction and operation of electric arc furnace [Direct and Indirect Arc]. Core and core less induction furnace, cupola, rotary and crucible furnaces. (7)

DEVELOPMENT OF LAYOUT AND FACILITIES: Layout, mechanisation and automation, fettling, inspection and pollution control. planning foundries of specified capacity for a particular alloy. (8)

DESIGN CONSIDERATIONS:Casting design, methoding, Gating and Risering calculations, improvement of yield and efficiency, simple problems in gating and risering for steels and cast irons. (8)

CASTING DEFECTS: Identification, analysis and Remedies. Fish bone diagram, FMEA and Y - Y analysis. (5)

COMPUTER APPLICATIONS: Solidification and simulation of metal casting-use of softwares. (3)

Total L: 45

REFERENCES:

1. Srinivasan N K, “Foundry Engineering”, Khanna Tech. Publication Co, New Delhi, 2011.
2. Jain P L, “Principles of Foundry Technology”, Tata McGraw-Hill Publishing Co., Ltd, New Delhi, 2009.
3. Heine R W, Loper and Rosenthal, “Principles of Metal Casting”, Tata McGraw Hill Publication. Co., 2012.
4. ASM Handbook, “Casting”, ASM Publication, 2010.
5. Peter Beelay, “Foundry Technology”, London, 2001.
6. Chakrabarti A K, “Casting Technology and Casting Alloys”, PHI Publishing Co, New Delhi, 2009.
7. John Campbell, “Casting”, Elsevier Publishing Amsterdam, 2011.

15YN04 WELDING TECHNOLOGY

3 0 0 3

INTRODUCTION: Joining techniques**,** Welding processes and grouping, welding terms (2)

ARC CHARACTERISTICS: Plasma, electron emission and ionization potential, arc temperature, influence of magnetic fields on arcs, arc blow, metal transfer, effect of polarity, effect of shielding gases. (2)

POWER SOURCES: Power source characteristics, static and dynamic characteristics, CC and CV power source designs, current and voltage relationships, solid state power sources, wave form controlled power sources. (2)

ARC WELDING PROCESSES: Detailed description about the process equipment, control of parameters, consumable, specifications for electrodes and filler metals and applications related to the following processes: Shielded metal arc welding, gas metal arc welding, flux cored arc welding, gas tungsten arc welding, plasma arc welding, submerged arc welding, stud arc welding. (17)

OTHER WELDING PROCESSES: Oxy-fuel gas welding, Electro Slag Welding, Resistance welding, Electron Beam Welding, Laser beam Welding, thermit welding , solid state welding processes – friction welding, friction stir welding, explosive welding, ultrasonic welding, diffusion welding. Weld overlay, thermal cutting and thermal spraying. Brazing and Soldering. (10)

HEAT FLOW IN WELDING: Heat transfer in weldments, dissipation of welding heat, cooling rates, weld metal cooling curves, peak temperature, calculating width of heat affected zones, solidification rate and effects of heat input. (3)

RESIDUAL STRESSES AND DISTORTION (3)

INTRODUCTION TO WELDING METALLURGY (2)

WELDING DEFECTS: Causes and remedial methods (3)

SAFETY IN WELDING (1)

Total L: 45

REFERENCES:

1. ASM Metals Hand Book, "Welding, Brazing and Soldering", ASM International, Metals Park, Ohio, 1993.
2. Nadkarni S V, "Modern Arc Welding Technology", Oxford IBH Publishers, 1996.
3. AWS Welding Handbook, "Welding Science & Technology", American Welding Society, 2001.
4. Howard B Cary, "Modern Welding Technology", Prentice Hall, New Jersey, 2002.
5. Parmar R S, "Welding Engineering and Technology", Khanna Publishers, 2003.
6. AWS Welding Handbook, "Welding Processes - Part 1", American Welding Society, 2004.
7. AWS Welding Handbook, "Welding Processes- Part 2", American Welding Society, 2004.

13YN05 MECHANICAL METALLURGY

2 2 0 3

PLASTIC DEFORMATION: Dislocations-types, burgers vector, theoretical cohesive strength and practically measured strength, deformation by slip, critical resolved shear stress, deformation by twinning, stacking faults. Dislocation theory-dislocation loop, dislocations in cubic and hexagonal lattices, stress fields and energies of dislocations, dislocation climb, intersection of dislocations, dislocation multiplication, dislocation pile-ups. Strain hardening of single crystals. (12+3)

FRACTURE: Types, Griffth's theory of brittle fracture, fractography, effect of temperature, stress raisers and strain rate on fracture behaviour. **Fracture mechanics**-stress intensity factor, fracture toughness, plane- strain toughness testing, crack opening displacement, probabilistic aspects of fracture mechanics. (8+2)

TENSION TEST: Engineering stress – strain curve and true stress-strain curve, instability in tension, measurement of tensile properties, factors affecting flow properties, notch tensile test. **Hardness test**-Brinell hardness-relationship between hardness and flow curve, Vickers hardness, Rockwell hardness, microhardness tests, hardness-conversion relationships. **Torsion Test**-Types, torsion test Vs tension test, hot torsion test. Overview of ASTM testing standards for tension, hardness and torsion tests, compression test. (10+4)

IMPACT TEST: Izod and Charpy tests, significance of transition–temperature curve, DBTT, factors affecting transition temperature. Overview of ASTM testing standard for impact test. (5+1)

FATIGUE AND CREEP: S-N curve, fatigue testing, factors affecting fatigue properties, structural features of fatigue failures, low cycle fatigue, Paris equation, Residual life estimation. **Creep**: creep curve, structural changes during creep, mechanisms of creep deformation, deformation mechanism maps, stress- rupture test, long term creep, Larson-miller parameter. Overview of ASTM testing standard for fatigue and creep test. Few case studies on the design of damage tolerant alloys. (10+5)

Total L: 45+T: 15 = 60

REFERENCES:

1. Dieter G E, "Mechanical Metallurgy", McGraw hill book company, 2001.
2. Hull D and Bacon D J, "Introduction to Dislocations", Butterworth- Heinemann, Oxford, 2001.
3. Courtney T H, "Mechanical Behavior of Materials", Overseas Press (India) Private Limited, 2006.

15YN51 OPTICAL METALLOGRAPHY LABORATORY

0 0 4 2

1. (a) Specimen preparation for metallurgical microscope.
   (b) Study of metallurgical microscope –various techniques like bright field, dark field, polarized light.
2. Study of cast irons in the unetched and etched conditions. (Grey, SG, White and Malleable)
3. Study of plain carbon steels. (Low, Medium and High carbon)
4. Study of heat treated steels (Hardened, tempered and case carburized steels)
5. Study of stainless steels and Tool steels.
6. Study of Aluminium and Copper base alloys.
7. Study of Nickel and Titanium base alloys.
8. Inclusion rating and Grain size measurement.
9. Colour Metallography and insitu metallography - a few examples.
10. Macro etching and electrolytic polishing and etching.

Total P: 30

REFERENCES:

1. Laboratory manual prepared by the Department of Metallurgical Engineering.
2. Kehl G L, “The Principles of Metallographic Laboratory Practice”, McGraw Hill Book Company, 1994.
3. George F Vander Voort, “Metallography: Principles and Practice”, McGraw Hill Book Company, 1984.
4. George F Vander Voort, “Applied Metallography”, Van Nostrand Reinhold Co., 1986.

15YN61 INDUSTRIAL VISIT & TECHNICAL SEMINAR

0 0 4 2

VISIT TO INDUSTRIES

Study tour/Industrial visit. Reports are to represent the observations of the students after the visits with their personal comments/suggestions.

TECHNICAL SEMINAR

Faculty will arrange for lectures by experts preferably from industries to highlight the recent technical and soft skill trends.

SEMESTER II

15YN06 EXPERIMENTAL TECHNIQUES IN METALLURGY

2 2 0 3

LIGHT MICROSCOPY: Macro examination, principle and working of optical microscope, specimen preparation, optical principles - numerical aperture, resolving power, depth of focus, depth of field, aberrations in optical microscopes and their remedial measures, different microscopic techniques-dark field microscopy, phase-contrast microscopy, polarized light microscopy, interference microscopy, high temperature microscopy; quantitative metallography. (10+3)

X-RAY DIFFRACTION: X-Ray Radiation –Properties, Generation of X-rays,X-ray absorption, Diffraction-Bragg's law, Reciprocal Lattice, Laue’s, rotating crystal and powder diffraction methods, X-ray diffractometer - principle, equipment and applications, X-ray filters and counters, Applications- Determination of crystal structure, lattice parameter, Crystallite Size calculation, Residual stress measurements. (8+3)

TECHNIQUES OF ELECTRON MICROSCOPY: Electron specimen interactions, electron optical instruments, transmission electron microscopy - specimen preparation, imaging modes, applications, selected area diffraction, scanning electron microscopy - operating modes and applications, electron probe microanalyser-qualitative and quantitative analysis, vacuum systems for electron microscopy. (10+3)

ADVANCED MICROSCOPIC TECHNIQUES: Scanning probe microscopy-Scanning Tunneling Microscopy, Atomic force microscopy- principle, instrumentation and applications, field ion microscopy - principle, instrumentation and applications. (6+1)

OPTICAL AND X-RAY SPECTROSCOPY: Optical emission spectroscopy, X-ray fluorescence spectroscopy - principle, equipment and applications. (4+1)

SURFACE CHEMICAL ANALYSIS TECHNIQUES: Auger Electron Spectroscopy–principle, instrumentation and applications in metallurgy; X-ray photoelectron spectroscopy - principle, instrumentation and applications; secondary ion mass spectroscopy - principle, instrumentation and applications. (5+2)

THERMAL ANALYSIS TECHNIQUES: Differential thermal analysis, Differential scanning calorimetry and Thermo-Gravimetric analysis - principles, instrumentation, results interpretation. (2+1)

DILATOMETRY, RESISTIVITY AND MAGNETIC MEASUREMENTS (2+1)

Total L: 45+T: 15 = 60

REFERENCES:

1. Angelo P C, "Materials Characterization", Reed Elsevier India Pvt Ltd, 2013.
2. Yang Leng, "Materials Characterization -Introduction to Microscopic and Spectroscopic Methods", John Wiley & Sons Pte Ltd Singapore, 2008.
3. Cherepin V T and Mallic A K, "Experimental Techniques in Physical Metallurgy", Asia Publishing Co, Bombay, 1967.
4. Cullity B D and Stock S R, "Elements of X-ray Diffraction", Prentice Hall, Inc, 2001.
5. Hebbar K R, "Basics of X-Ray Diffraction and its Applications", I.K. International Publishing House, New Delhi, 2007.
6. ASM Handbook, "Materials Characterisation", ASM international, USA, 1986.

15YN07 FORMING PROCESSES

2 2 0 3

THEORY OF PLASTICITY: State of stress, components of stress, symmetry of stress tensor, principal stresses, stress deviator, Von Mises, Tresca yield criteria, comparison of yield criteria, Forming load calculations. (6+1)

FUNDMENTALS OF METAL FORMING: Flow stress determination, Temperature in metal forming, Hot, Cold and Warm working, Strain rate effects, Metallurgical structures, friction and lubrication, Deformation zone geometry, Hydrostatic pressure, Workability, Residual stresses, deformation processing maps. (7+2)

FORGING AND ROLLING: Forging -types of presses and hammers. Open die forging and closed die forging, die design, forging in plane strain, forging defects- causes and remedies.Rolling: Classification of rolling processes, types of rolling mills, hot and cold rolling, rolling of bars and shapes, forces and geometrical relationship in rolling, rolling defects- causes and remedies, ring rolling and thread rolling. (10+4)

EXTRUSION AND DRAWING: Direct and indirect extrusion, variables affecting extrusion, Port-hole extrusion die, hydrostatic extrusion, defects and remedies, simple analysis of extrusion, tube extrusion and production of seamless pipe and tube., Drawing of rods, wires and tubes. (6+3)

SHEET METAL FORMING: Forming methods - Shearing, blanking, bending, stretch forming, deep drawing. Types of dies used in press working, defects in formed part, sheet metal formability, formability limit diagram, Hydroforming. (6+1)

SEVERE PLASTIC DEFORMATION: Introduction, equal channel angular pressing (ECAP), accumulative roll-bonding (ARB), repetitive corrugating and straightening (RCS), applications. (5+2)

HIGH VELOCITY FORMING AND SUPERPLASTIC FORMING: Comparison with conventional forming. Explosive forming, Electro hydraulic, Electro Magnetic forming, Dynapak and Petro-forge forming. Superplasticity- definition, merits and demerits, superplastic forming methods. (5+2)

Total L: 45+T: 15 = 60

REFERENCES:

1. Betzalel Avitzu, "Metal Forming- Processes and Analysis", Tata McGraw Hill, 1977.
2. Dieter G E, "Mechanical Metallurgy", McGraw Hill, 2001.
3. ASM Metals Handbook, "Forming & Forging", Metals Park, Ohio, USA, 1998.
4. William F Hasford and Robert M Caddell, "Metal Forming: Mechanics and Metallurgy", Cambridge University Press P.ltd., 2007.

15YN08 HEAT TREATMENT AND SURFACE MODIFICATION

3 0 0 3

PRINCIPLES OF HEAT TREATMENT: Review of Phase diagrams and phase transformations. (6)

HEAT TREATMENT EQUIPMENT: Furnaces, Calibration of thermocouple, Quenching methods, fixtures, control of furnace atmosphere, temperature control, Design of heat treatment furnaces. (3)

HEAT TREATMENT OF STEEL: Effect of alloying elements on Fe-Fe_3C diagram, Annealing(different types), normalizing, hardening - Quenching media - Martensite formation.TTT and CCT diagrams. Hardenability and measurement of hardenability-Influence of alloying elements. Tempering-Temper brittleness, Sub zero treatment-Control of retained austenite. Austempering, Martempering and Thermo-mechanical treatments. (10)

SURFACE MODIFICATION TECHNIQUES: Flame and induction hardening. Carburising, nitriding, carbonitriding, boriding, electron beam and laser beam hardening .PVD and CVD processes, sputter coating, ion plating, ion implantation, spray coatings. (10)

HEAT TREATMENT OF FERROUS ALLOYS: Stainless steels, Tool steels and Cast irons, maraging steels, HSLA steels and dual phase steels. (6)

HEAT TREATMENT OF NON-FERROUS ALLOYS: Aluminium alloys, Magnesium alloys, Titanium alloys, and Ni-base alloys. (6)

INSPECTION AND QUALITY CONTROL: Causes and remedies for defects (like low hardness and strength, soft spots, oxidation and decarburization, over heating and burning, quench cracks, distortion and warping) in heat-treated parts. (4)

Design for heat treatment.

Total L: 45

REFERENCES:

1. Rajan and Sharma, "Heat Treatment, Principles and Techniques", Prentice Hall of India, 2010.
2. Vijendra singh, "Heat treatment of metals", Standard Publishers distributors, 2005.
3. Prabhudev K H, "Handbook of Heat Treatment of Steels", Tata-McGraw Hill Publications. Co. Ltd., 1988.
4. American Society of Metals, "Metals Handbook", Volume IV, A.S.M., Metals park, Ohio, USA, 1991.
5. Sudharsan T S, "Surface Engineering", Ohio State University, 1992.
6. Karl Eric Thelning, "Steel and its heat treatment", Butterworth Publications, 2000.

15YN09 IRON AND STEEL MAKING

3 0 0 3

INTRODUCTION TO PRODUCTION OF IRON AND STEEL: History of iron and steel making, evolution of modern steel making, overview of steel making in India and aboard, general layout of integrated steel plants. (3)

RAW MATERIALS AND THEIR PREPARATION: Coke manufacture- by-product coke ovens, iron ores, in India, iron ore beneficiation, agglomeration methods - principle and mechanism of sintering, pelletisation, fluxes, testing of raw materials, raw materials for steel making, steel making refractories, pre-treatment of hot metal prior to steel making. (6)

PHYSICAL-THERMAL-CHEMICAL PROCESSES IN IRON MAKING: physical, thermal and chemical profiles, physical chemistry of blast furnace reactions - carbon-oxygen reaction, gas-solid reactions, slag-metal reactions, desulphurisation and desiliconisation, RAFT calculation. (6)

PHYSICAL CHEMISTRY OF STEEL MAKING: Thermodynamics, kinetics and transport phenomena in steel making**,** refining slags, slag – metal refining reactions. (6)

BLAST FURNACE PLANT AND PROCESS: Layout, constructional features and accessories of the blast furnace, charging equipment, burden distribution, gas cleaning, hot blast stove, operational irregularities, metal and slag, High top pressure, bell-less top, pulverised coal injection, humidification of blast, pre-reduced ore. (6)

ALTERNATE IRON MAKING: Sponge iron production – rotary kilns and Fastmet processes, Finmet, HyL, Midrex processes, Smelting Reduction – Corex, Hismelt, Finex, Fastmelt, and ITmK3 processes. (5)

STEEL MAKING PROCESSES : Overview of Bessemer converters, open hearth practice: furnace and operation, Electric arc furnace steel making, LD process - plant and equipment, steel making practice, slag-metal-gas interaction, oxygen bottom blown process, , combined blowing processes, CONARC process, EOF process. (7)

SECONDARY STEEL MAKING: Deoxidation, desulphuisation, laddle furnace, decarburization methods, vacuum degassing methods, Injection metallurgy. (3)

TEEMING METHODS: Ingot casting of steel - fundamentals of solidification, rimming, capped and killed steels, ingot defects; Continuous casting of steel - heat transfer and solidification in continuous casting, tundish design and operation, continuous casting of slabs and blooms, metallurgical defects. (3)

Total L: 45

REFERENCES:

1. Ahindra Ghosh and Amit Chatterjee, "Iron Making and Steel Making-Theory and Practice", PHI Learning Private Ltd., New Delhi, 2010.
2. Tupkary R J and Tupkary V R, "An Introduction to Modern Iron Making", Khanna Publishers, New Delhi, 2010.
3. Tupkary R J and Tupkary V R, "An Introduction to Modern Steel Making", Khanna Publishers, New Delhi, 2010.
4. Wakelin D H, "The Making, Shaping and Treating of Steel: Iron Making", The AISE Steel Foundation, 1999.
5. Maarten Geerdes, Hisko Toxopeus (coaut.), Cor van der Vliet (coaut.), "Modern blast furnace iron making : an Introduction", IOS Press, 2012.

15YN10 ENVIRONMENTAL DEGRADATION OF METALS

3 0 0 3

THERMODYNAMICS OF CORROSION: Electrode potential – standard and reference electrodes, electrode and cell representations – electrochemical cells – galvanic and concentration cells. Nernst equation, EMF series – free energy criteria for corrosion reaction – thermodynamic Vs kinetic considerations - Pourbaix diagram (Fe, Ni, Al & Zn). Faradays laws, corrosion rates expressions. (9)

KINETICS OF CORROSION: Corrosion current density and corrosion rate, exchange current density–activation and concentration polarization-Tafel equation, mass transport control, mixed potential theory and behaviour of galvanic couples, effect of oxidizer, combined polarization, factors affecting polarizations and rate of corrosion. Passivity-potentiostatic polarization curves, affecting passivity, passivating materials, factors. Kinetics of high temperature corrosion, Pilling-Bedworth ratio, protective and non protective oxides. (9)

FORMS OF CORROSION: Atmospheric corrosion, galvanic corrosion, general biological corrosion. Localized corrosion-filiform corrosion, crevice corrosion, pitting corrosion, localized biological corrosion. Metallurgically influenced corrosion-inter granular corrosion, de-alloying. Mechanically assisted corrosion-erosion corrosion, cavitation corrosion, fretting corrosion, corrosion fatigue, environmentally induced cracking-mechanisms of stress corrosion cracking and hydrogen embitterment (9)

CORROSION MONOTORING AND TESTING: Purpose and classification, weight loss method, salt spray test, tests for intergranular corrosion, and stress corrosion cracking. Electrochemical polarization techniques, Tafel extrapolation, linear polarization, AC impedance methods- electrochemical impedance spectroscopy. Application of -NDT techniques, Outline of on stream and off stream corrosion monitoring methods. (9)

PREVENTION OF CORROSION: corrosion control by design, selection of materials-alloying-stainless steel and brass, oxidation resistant materials, cathodic and anodic protection methods, corrosion inhibitors, anodic, cathodic and mixed inhibitors – vapour phase inhibitors, applications, surface conversion processes. Metallic coatings, ceramic coatings. Superhydrophobic and self heating coatings. (9)

Total L: 45

REFERENCES:

1. Chatterjee U K, “Environment degradation of metals”, Marcel Dekker Inc., 2001.
2. Rajnarayan, “Metallic Corrosion and Prevention”, Oxford Publications, 1988.
3. Mars G Fontana, “Corrosion Engineering”, McGraw Hill Inc., 1987.
4. Herbert H Uhlig and Winston Revie, “Corrosion and Corrosion Control - An Introduction to Corrosion Science and Engineering”, John Wiley & Sons, 1985.
5. Kenneth R Trethewey and John Chamberlain, “Corrosion for Science and Engineering”, Longman Inc., 1996.
6. Denny A Jones, “Principles and Prevention of Corrosion”, Prentice Hall Inc., 1996.
7. Zaki Ahmad, Digby Macdonald, “Principles of Corrosion Engineering and Corrosion Control”, Butterworth-Heinemann, 2013.
8. ASM Hand book, “Corrosion”, ASM International, 2001.

15YN52 CASTING, JOINING AND FORMING LABORATORY

0 0 4 2

CASTING:

1. a) Moisture Content of Foundry Sand
   b) AFS Grain Fineness Number
2. a) Sand Strength Tests
   b) Mould/Core Hardness Test and Compactability Test
   c) Permeability Test
   d) Shatter Index Test
3. a) Mouldability
   b) Flowability

JOINING:

4. Microstructure and transverse hardness characterization of carbon steel weldments
5. Microstructure and transverse hardness characterization of stainless steel weldments
6. Implant test and diffusible hydrogen measurement.

FORMING:

7. Determination of n and K values using tension test.
8. Cold working of low and high stacking fault energy materials.
9. Determination of friction coefficient using ring compression test

Total P: 30

REFERENCES:

1. Laboratory Manuals prepared by Department of Metallurgical Engineering.

SEMESTER III

15YN53 TESTING AND CHARACTERIZATION LABORATORY

0 0 4 2

TESTING LABORATORY:

1. Visual or Optical Test (VT/OT)
2. Penetrant Test
3. Magnetic Particle Test
4. Eddy Current Test
5. Ultrasonic Test and Study of Film Radiography

CHARACTERIZATION LABORATORY:

1. Quantitative Metallography
2. X-ray Diffractometre
   (a) Determination of crystal structure, lattice parameter
   (b) Determination of crystal size and lattice strain
3. Transmission electron microscope
   (a) Demonstration on sample preparation
   (b) SAD pattern indexing
4. Scanning electron microscope
5. Optical emission spectroscopy

Total P: 30

15YN71 PROJECT WORK - I

1. Identification of a real life problem in thrust areas.
2. Developing a mathematical model for solving the above problem.
3. Finalisation of system requirements and specification.
4. Proposing different solutions for the problem based on literature survey.
5. Future trends in providing alternate solutions.
6. Consolidated report preparation of the above

SEMESTER IV

15YN72 PROJECT WORK - II

1. Identification of a real life problem in thrust areas.
2. Developing a mathematical model for solving the above problem.
3. Finalisation of system requirements and specification.
4. Proposing different solutions for the problem based on literature survey.
5. Future trends in providing alternate solutions.
6. Consolidated report preparation of the above

ELECTIVES

15YN21 NON-DESTRUCTIVE EVALUATION

3 0 0 3

OVERVIEW: Concepts of Non-Destructive testing, Discontinuities and Defects, Various physical characteristics of materials and their applications in NDT, Relative merits and limitations of NDT, Types of NDT techniques, Introduction to codes and standards for NDT. (3)

SURFACE TECHNIQUES: Visual or Optical Testing (VT/OT): Direct and remote visual inspection–Visual Aides. Penetrant Testing (PT): Principle, applications, advantages and limitations, Dyes, developers and cleaners, Fluorescent penetrant test. Practical demonstrations on VT and PT. (5)

MAGNETIC TECHNIQUES: Magnetic Particle Testing (MPT): Principles, applications, magnetization methods, magnetic particles, Dry particle technique and Wet fluorescent particle technique, demagnetization, Advantages and limitations. Practical demonstrations on MPT. Magnetic Flux Leakage Testing (MFL): Principle, Instrumentation and applications. (4)

ELECTROMAGNETIC INDUCTION TECHNIQUES: Principle, Instrumentation and applications of Eddy Current Testing **(ECT)** and Remote Field Testing (RFT). (4)

ULTRASONIC TESTING (UT): Types of Ultrasonic waves, Characteristics of ultrasonic waves, Attenuation, Couplants, Probes, EMAT. Inspection methods-Pulse echo, Transmission and Phased Array techniques (PAUT) , Types of scanning and displays, Angle beam inspection of welds, Time of Flight Diffraction (TOFD) technique, LASER ultrasonic testing, Calibration: ASTM Test blocks, IIW - reference blocks, Practical demonstrations on UT. (12)

RADIOGRAPHY TESTING (RT): Sources - X-rays and Gamma rays and their characteristics - Absorption, scattering. Filters and screens, Imaging modalities – Film radiography and Digital Radiography (Computed, Direct, Real Time, CT scan). Problems in shadow formation, Exposure factors, Inverse square law, Exposure charts, Radiographic equivalence. Penetrameters, Safety in radiography, Practical demonstrations on RT film interpretation. (12)

SPECIAL TECHNIQUES: Principle, Instrumentation and applications of Acoustic Emission Testing (AET), Infra Red Thermography (IRT), Pressure and Leak Testing, LASER Shearography. (5)

Total L: 45

REFERENCES:

1. ASM Metals Handbook, “Non-Destructive Evaluation and Quality Control”, American Society of Metals, Metals Park, Ohio, USA,2001.
2. Mc Gonnagle W T, “Non-Destructive Testing”, McGraw Hill Book Co., 1988.
3. Louis Cartz, “Non-Destructive Testing”, ASM International, Metals Park Ohio, US, 1995.
4. Barry Hull and Vernon John, “Non Destructive Testing”, ELBS / Macmillan, 1989.

15YN22 THERMODYNAMICS OF MATERIALS

3 0 0 3

INTRODUCTION: System and surrounding, Classification of systems, Path and state properties, Thermodynamic processes, Thermodynamic equilibrium, Reversible and Irreversible processes, Law’s of Thermodynamics-,First,second, third and zeroth law of thermodynamics and their applications. (5)

THERMODYNAMICS OF METALLURGICAL REACTIONS: Concepts of enthalpy, entropy, Free energy**,**Heat capacity**, Effect of temperature on thermodynamic properties**, Gibbs- Helmholtz equation, Clausius - Clayperon equation-effect of pressure on equilibrium temperature (H_2O and Fe system),Ellingham Diagram-Oxides,sulphides and chlorides, equilibrium constant-applications to metallurgical reactions. (10)

THERMODYNAMICS OF SOLUTIONS:Binary Solutions; Ideal solutions - Raoult's law, activity, Activity coefficient, Henry's law, partial and integral molar quantities, Regular solutions, Real solutions, Sievert's law. Gibbs Duham equation and its application. (12)

THERMODYNAMICS OF PHASE TRANSFORMATIONS: Phase rule, Phase stability-Free energy –temperature diagram, Application of free energy - composition diagrams to the development of isomorphous and eutectic phase diagrams, Thermodynamics of order of transformation-First order and second order transformations, Nucleation and growth-thermodynamics and kinetics of homogeneous nucleation- extension to heterogeneous nucleation, application of thermodynamics in Fe-C system, precipitation hardening- thermodynamics and kinetics. (12)

Total L: 45

REFRENCES:

1. Porter D A and Easterling K E, “Phase Transformations in Metals and Alloys”, Chapman and Hall, UK, 2002.
2. David R Gaskell, “Introduction to the Thermodynamics of Materials”, Taylor & Francis, UK, 2003.
3. Upadhyaya G S and Dube R K, “Problems in Metallurgical Thermodynamics & Kinetics”, Pergamon, 1977.
4. Swalin R A, “Thermodynamics of solids”, John Wiley Sons Inc., 1966.
5. Mohanty A K, “Rate Processes in Metallurgy”, PHI learning PVT ltd, New Delhi, 2009.
6. Ray H S and Ghosh A, “Principles of Extractive Metallurgy”, New Age International publishers, 2007.
7. Tupkary R H, “Introduction to Metallurgical Thermodynamics”, TU publishers, 1995.

15YN23 FERROUS AND NON FERROUS ALLOYS

3 0 0 3

INTRODUCTION TO SPECIAL STEELS: Effect of alloying elements in Fe-Fe_3C diagram and in formation of phases such as Ferrite, Austenite, Martensite, Carbides and Bainite. (2)

MARAGING STEELS: Manufacture, structure, property, heat treatment and applications of maraging steels. (2)

HSLA AND MICROALLOYED STEELS: Effect of alloying elements in HSLA and Micro-alloyed steels**.** Production, heat treatment, microstructure, properties and applications of Low and ultra low carbon steels, thermo-mechanical processing steels, Quenched and tempered steels, armour steels, DP steels, IF steels, TRIP steels, Micro-alloyed steels, and Bainitic steels. (6)

STAINLESS STEELS: Types of stainless steels; ferritic, martensitic, austenitic, precipitation hardening, duplex, heat resisting, their manufacture, classifications by AISI system, compositions, properties, structure and applications. Nickel free stainless steels, high nitrogen stainless steels (HNS)-their manufacture, structure, properties and applications. Embrittlement and Sensitization- causes and remedial measures for stainless steels. (6)

TOOL STEELS: Classifications of tools steels by AISI System, composition, properties, applications of tool steels. Heat treatment and microstructure of tool steels (3)

MISCELLANEOUS STEELS: Specification, composition, structure, properties and applications of silicon steels, high manganese steel. Steels for high temperature applications-1Cr0.5Mo steel, 2.25Cr1Mo steel, 9Cr1Mo steel, etc. Steels for automobile applications-High Mn TWIP steels, etc., (4)

INTRODUCTION TO NON FERROUS ALLOYS (with ASTM standards): (1)

COPPER AND COPPER ALLOYS: Properties and applications of metallic copper; influence of alloying elements in copper alloys. Classifications of copper base alloys and their compositions, heat treatment details, microstructure, properties and applications. (4)

ALUMINIUM: Properties and uses of metallic aluminium; classification of aluminium alloys, wrought and cast alloys; heat treatable and non-heat treatable alloys; Physical metallurgy of Al alloys, strengthening mechanisms in non-heat treatable alloys and heat treatable alloys; effect of alloying elements and impurities; properties; Al-Li alloys. (5)

MAGNESIUM: properties and applications of magnesium and magnesium alloys; influence of alloying elements-Al, Mn, Zn, Si, Ag, Th, Zr; classification-cast alloys and wrought alloys. (3)

TITANIUM: Introduction; Ti and its alloying capability, Alloying elements-Alpha stabilisers; beta stabilisers; alpha titanium alloys; beta titanium alloys; alpha-beta titanium alloys; structure-property correlations (4)

NICKEL: Metallurgy of nickel base alloys-Alloying elements and their effects-Nickel base superalloys composition; melting, forging; solid solution alloys, precipitation hardenable alloys, ODS alloys heat treatment, properties and applications; Nickel-iron base alloys, heat treatment, properties and applications. (5)

Total L: 45

REFERENCES:

1. Balram Gupta, “Aerospace Materials”, S Chand and Co., New Delhi, 1996.
2. Clark and Varney, “Physical Metallurgy for Engineers”, Affiliated East West press, New York, 1987.
3. Edgar C Bain and Paxton H W, “Alloying Elements in steel”, American Society for Materials, 1966.
4. Wilson R N, “Metallurgy and Heat Treatment of Tool Steels”, McGraw Hill, New York, 1975.
5. Lula R, “Stainless Steels”, ASM, Ohio, 1990.
6. Brick, Gordon and Pense, “Structure and Properties of Engineering Materials”, McGraw Hill Book Co., New York, 1992.
7. ASM Hand Book, “Casting”, ASM Hand Book Committee, 1998.

15YN24 POWDER METALLURGY

3 0 0 3

INTRODUCTION: Steps in Powder Metallurgy, scope, advantages, limitations specific examples, comparison with conventional techniques, problems. (1)

POWDER PRODUCTION TECHNIQUES: Classification of synthesis techniques. Preparation of powders; metallic, ceramic and composite powders. Characteristic features and examples of powders produced by various methods- Detailed discussion of atomization and Mechanical Alloying.- Brief discussion on SHS and PIM. (7)

POWDER CHARACTERISATION: Basic concepts of sampling and characterization. Techniques for detailed analysis of composition, particle size, shape, apparent and tap densities- particle size distribution area of powders. (6)

POWDER CONDITIONING AND CONSOLIDATION: Annealing, mixing and blending- equipments. Techniques of compaction, Die compaction- equipments- methods, problems, design considerations. Properties of green compacts. High density processing,- Cold Isostatic Pressing, powder rolling and powder forging. (6)

SINTERING: Theory of solid state and liquid phase sintering. Stages in sintering, structure and property changes. Sintering mechanisms with examples. Other types of sintering. Sintering furnaces-types. Sintering atmospheres- types, production, properties and applications- Properties of sintered compacts. High temperature consolidation-Hot pressing and Hot Isostatic Pressing. (HIP) (12)

SECONDARY OPERATIONS AND FINISHING: Machining, plating, heat treatment and infiltration, sizing and coining. (3)

P/M PRODUCTS - Production of bearings, friction materials, carbide tools, P/M magnetic materials, tools and dispersion strengthened alloys by P/M. (5)

IMPORTANT P/M ALLOYS AND APPLICATIONS OF P/M PARTS: Iron base alloys, Aluminium base alloys, Nickel base alloys, titanium base alloys- processing. Applications of commercial P/M Alloys in automobile, aerospace, nuclear and miscellaneous applications of P/M parts. (5)

Total L: 45

REFERENCES:

1. Angelo P C and Subramanian R, "Powder Metallurgy Science, Technology and Applications", Prentice Hall of India, New Delhi, 2012.
2. Metals Handbook, "Powder Metallurgy, ASM Metals Park, Ohio, 1989.
3. Randall M German, "Powder Metallurgy of Iron & Steel", John Wiley & Sons Inc. New York, 1998.
4. Upadhayaya G S, Upahyaya A and Tagaki K, "Powder Metallurgy-Science Technology and Materials", Universities Press, UK, 2011.

15YN25 FOUNDRY METALLURGY

3 0 0 3

SOLIDIFICATION OF METALS AND ALLOYS: Solidification of castings-microstructure development. Effect of composition, moulding materials and cooling rate on solidification pattern. Shrinkage of casting and directional solidification of castings. (3)

CAST IRONS: Graphitization. Types, size of graphite for Grey Cast Iron and S.G.Iron. Effect of normal and alloying elements in Cast Irons. Composition ,properties ,microstructure ,application and production of Austenitic Cast Irons, High silicon Cast Irons, High chrome Cast Irons, and Ni-Hard cast irons. Grey cast of S.G.Iron, Austempered S.G.Iron. C.G.Iron and Malleable Cast Iron. Composition control for Cast Irons Simple Problems in composition control. Specifications IS, BS,EN AND ASTM standards, Inoculation and inoculation techniques (12)

STEELS: Effect of normal and alloying elements in steels. Compositional aspects and properties of alloy steels. Melting Procedure and composition control for carbon steels, low alloy steels and stainless steels using arc and induction furnaces. Simple Problems in composition control. Steel melting in AOD, VOD and Vacuum furnaces. Slag-Metal reactions, different slag practices- Desulphurization - Dephosphorisation. Specifications for carbon steels, low alloy steels and stainless steels as per ASTM Standards. Modification and grain refinement of steels. (12)

NON-FERROUS CAST ALLOYS: Specifications, composition, properties and phase diagrams of Copper, Aluminium, Magnesium, zinc and Nickel base alloys. Melting Procedure and composition control for Al alloys, Mg alloys, Nickel alloys, Zinc alloys and copper alloys. Modification and grain refinement of Al alloys. Simple Problems in composition control. Specifications IS, BS, EN AND ASTM standards (12)

.

GASES IN METALS AND DEGASSING TECHNIQUES (2)

FLUIDITY: Definition, factors affecting and measurement of fluidity. (2)

RESIDUAL STRESSES: Origin, effects and stress relieving operations. (2)

Total L: 45

REFERENCES:

1. Heine R W Loper and Rosenthal, "Principles of Metal Casting", Tata McGraw Hill. Publication. Co., 2012.
2. ASM Handbook, "Casting", ASM Publication, 2010.
3. Peter Beelay, "Foundry Technology", Butterworth, London, UK, 2001.
4. John Campbell, "Casting", Elsevier Publishing Amsterdam, 2011.

15YN26 WELDING METALLURGY

3 0 0 3

WELD SOLIDIFICATION AND TRANSFORMATION IN WELDMENTS: Weld solidification, Absorption of gases, liquid metal reactions, solid state transformations in weldments, strengthening mechanisms in weld metals, heat affected zones (5)

WELDING OF CARBON STEELS AND LOW ALLOY STEELS: Phase transformation, Hydrogen induced cracking, carbon equivalent, preheating and post heating, solidification cracking, lamellar cracking, reheat cracking. (6)

WELDING OF STAINLESS STEELS: Welding of austenitic, ferritic, martensitic, duplex and precipitation hardenable stainless steels. General Welding characteristics, Weld microstructures, Weld cracking and other metallurgical difficulties, Use of Constitution diagrams (Schaeffler, Delong, WRC-1992), Filler metal selection, Dissimilar welds with stainless steels. (8)

WELDING OF CAST IRONS: Weld metal and HAZ microstructures, Defects and remedies, Filler metal selection. (4)

WELDING OF ALUMINIUM ALLOYS: Oxide formation, Hydrogen solubility, Difficulties due to electrical and thermal characteristics, sensitivity to weld cracking. Filler metal selection. Weldability of heat treatable and non-heat-treatable aluminium alloys. (5)

WELDING OF NICKEL ALLOYS, TITANIUM ALLOYS AND COPPER ALLOYS: Weld metal and HAZ microstructures, Defects and Remedies, Filler metal selection. (6)

WELDING OF SPECIAL ALLOYS: Welding of magnesium alloys, tool steels and clad metals. (3)

WELDABILITY AND WELDABILITY TESTING:Factors affecting weldability, cold cracking tests, hot cracking tests, Gleeble test, Mechanical tests (emphasis on tension and bend tests) (5)

WELDING QUALIFICATIONS: Welding Procedure Specification, Procedure qualification and welder qualification. (3)

Total L: 45

REFERENCES:

1. Lancaster J F, "Metallurgy of Welding", George Allen Co, Boston, 1980.
2. ASM Metals Hand Book, "Welding, Brazing and Soldering", ASM International, Metals Park, Ohio, USA, 1993.
3. Linnert G E, "Welding Metallurgy", AWS, New York, 1995.
4. AWS Welding Handbook, "Materials and Applications - Part 1", AWS, New York, 1996.
5. AWS Welding Handbook, "Materials and Applications - Part 2", AWS, New York, 1998.
6. Sindo Kou, "Welding Metallurgy", John Wiley & Sons, 2003.

15YN27 SELECTION OF MATERIALS FOR MECHANICAL DESIGN

3 0 0 3

MATERIALS AND PROPERTIES: Brief outline of classes of engineering materials and their evolution, Definition of materials properties, Displaying material properties using materials selection charts, Forces for change in materials selection and design, Materials and the environment. (6)

FACTORS IN SELECTION PROCESS: Design process - types of design, design requirements, Function, Material attributes, Shape and Manufacturing processes - Materials processing and design processes and their influence on design, Process attributes, Systematic process selection, Process selection diagrams, Process cost, Energy consumption for production, Material costs, Availability, Recyclability, Environmental consideration. (10)

MATERIALS SELECTION PROCESS: Materials selection methods: Screening, Ranking- weighted ranking, Performance indices- Materials selection charts, Deriving property limits and material indices, Structural indices. (4)

SELECTION OF MATERIAL AND SHAPE: Shape factors, Efficiency of standard sections, Material limits for shape factors, Material indices which include shape, The microscopic or microstructural shape factor, Co-selecting material and shape. (4)

CASE STUDIES ON APPLICATIONS: Automobile materials (Body and Crank shaft), Marine structural materials (Hull and Propeller), Aircraft structural materials (Wings and landing gears), Materials for space (Gas turbines and Nose), Materials for power generation machinery (Boilers and Pressure vessels), Materials for medical applications (Surgical knives and Bone replacements), Chemical and petrochemical industries (Acid storage tanks and Fuel carrying pipes). (18)

MATERIALS SELECTION PROJECT: Students will carry out a materials selection exercise for a hypothetical design project, identifying selection parameters and potential materials. (3)

Total L: 45

REFERENCES:

1. Ashby M F, "Materials Selection in Mechanical Design", Butterworth- Heineman, New York, 2005.
2. Dieter G E, "Engineering Design: A Materials and Processing Approach", McGraw-Hill, 2000.
3. ASM Handbook, "Materials Selection and Design", ASM International, 1997.
4. Petroski H, "Invention by Design", Harvard University Press, Cambridge,MA,1996.
5. Charles J A and Crane F A A, "Selection and Use of Engineering Materials", Butterworth-Heinemann Ltd., 1989.

15YN28 CERAMICS AND POLYMERS

3 0 0 3

CERAMICS CRYSTAL SYSTEMS: Crystal Structures of Ceramics (Pauling's Rules),Silicate Structures, Structures of Covalent ceramics, problems on crystal systems ,Structures of Glasses and properties . Simple problems involving Packing Fraction, critical radius ratio and density. Defects In Ceramics-Problems. (7)

PROPERTIES AND APPLICATIONS OF ENGINEERING CERAMICS: Mechanical properties-Electrical Properties- Thermal properties-Optical Properties of engineering ceramics –Simple problems - examples and applications. (8)

PRODUCTION AND FORMING TECHNIQUES: Solution synthesis routes-Sol gel, Combustion, Precipitation methods-Solid state methods **-** slip and slurry casting-applications- Powder processing equipment and process details of hot pressing, Hot Isostatic Pressing and Cold Isostatic Pressing, Sintering-Liquid Phase sintering. (6)

MECHANICAL BEHAVIOUR OF CERAMICS: Elasticity and brittle fracture- Toughening Mechanisms,Weibull Statistics and Design, Thermal Shock Resistance- Glass – elastic behaviour, strength and fracture. (6)

INTRODUCTION TO POLYMERS: Classification-thermoset, thermoplastics and elastomers. Structure of polymers-crystalline and amorphous polymers - concept of Glass Transition Temperature (Tg), Polymerization- types and mechanisms with examples, Degree of polymerization - molecular weight of polymers-problems, Polymer additives-Examples and properties, Applications of engineering plastics. Elastomers - types, properties, examples. and application. (6)

MECHANICAL BEHAVIOUR OF POLYMERS: Viscoelasticity-creep and stress relaxation in polymers. Yielding and fracture of polymers, Crazing of polymers. (6)

PROCESSING & SELECTION OF POLYMERS: Processing of thermoset and thermoplastic polymers-blow moulding,Injection moulding,Vaccum forming ,Thermoforming,compression moulding-Selection Criteria for Polymers with Examples. (6)

Total L: 45

REFERENCES:

1. Gowariker V R, Viswanathan N V and Jayadev Sreedhar, “Polymer Science”, New Age International P Ltd., 2005.
2. Michael Barsoum, “Fundamentals of Ceramics”, Mc Graw Hill Publishing Co., Inc., 1997.
3. William F Smith, “Foundations of Materials Science and Engineering”, McGraw-Hill Inc, New York., 1993.
4. Nobuka Ichinose, “Introduction to Fine Ceramics”, John Wiley & Sons, USA, 1987.
5. Chawla K K, “Ceramic Matrix Composites”, Chapman and Hall, UK, 1993.
6. Kingery W D, “Introduction to Ceramics”, John Wiley, USA, 1960.
7. Kenneth G Budinski, “Engineering Materials: Properties and selection”, Prentice Hall, 2002.

13YN29 COMPOSITES

3 0 0 3

INTRODUCTION: Composite material – definition – classification. Examples and applications for each class. (2)

FIBER COMPOSITES: Constituents - functions of fiber and matrix - Properties of fibers - Critical fiber length - Aligned and random fiber composites. Property prediction - Rule of Mixtures - Simple problems. Production of fibers : Glass fibers, boron, carbon, alumina, metallic fibers, and ceramic fibers. Matrix materials: metallic, polymer and ceramic matrix materials - Concept of interfaces and interfacial reactions in fiber composites. Tensile strength of continuous and discontinuous composites. Concept of fracture modes in fiber composites. (12)

POLYMER MATRIX COMPOSITES: Types- Processing-Thermal matrix composites – Hand layup and spray technique, filament winding, Pultrution, resin transfer moulding, autoclave moulding-Thermoplastic matrix composites-Injection moulding, film stacking – Diaphragm forming – Thermoplastic tape laying, Mechanical properties –.Applications. (7)

METAL MATRIX COMPOSITES: Matrices and reinforcements. Processing – Solid state, liquid state, deposition and insitu techniques MMCs applications. (6)

CERAMIC MATRIX COMPOSITES: Ceramic matrix materials – Processing – Hot pressing, liquid infiltration technique, Lanxide process, insitu chemical reaction techniques – CVD, CVI, solgel process. Interface in CMCs. Mechanical properties– Applications. (7)

CARBON / CARBON COMPOSITES: Processing, Properties and Applications. (2)

PARTICULATE COMPOSITES: Types - True particulate and Dispersion strengthened composites - Function and examples of dispersoids - Particle size - interparticle spacing-simple problems- Examples of particulate composites. (3)

LAMINAR COMPOSITES: Types - Layered and honeycomb structures – examples manufacture and applications. (3)

JOINING COMPOSITE MATERIALS, DESIGN OF COMPOSITES. (3)

Total L: 45

REFERENCES:

1. Mathews F L and Rawlings R D, "Composite Materials: Engineering and Science", CRC Press and Wood head Publishing Limited, 2002.
2. Krishnan K Chawla, "Composite Materials Science and Engineering", Springer, 2001.
3. Derek Hull, "Introduction to Composite Materials", Cambridge University Press, 1988.
4. "Handbook of Composites", American Society of Metals, 2001.

15YN30 METALLURGICAL FAILURE ANALYSIS

3 0 0 3

INTRODUCTION TO FRACTURE MECHANICS: Griffth theory Brittle fracture. Irwins approach to fracture toughness. Crack opening Displacement J integral evaluation and R curve and its use. (5)

FRACTURE: Classification and identification of various types of fractures. Ductile and brittle fracture - Fracture origin, initiators, characteristics of ductile and brittle fracture. Ductile to brittle transition (DBT), Significance of Transition. Temperature curve, Metallurgical factors affecting Transition – Temperature, Drop weight test and other large scale tests. (6)

FAILURE ANALYSIS: Fundamental sources of failures- Deficiencies in design, material, processing, service and maintenance, Stages of failure analysis. (3)

FATIGUE FAILURE: General concepts, Fracture characteristics; Factors affecting fatigue life. Case studies**.** (6)

CORROSION FAILURES: Overview of various types of corrosion, Factors influencing corrosion failures, analysis of corrosion failures. Case studies**.** (5)

WEAR FAILURES: role of friction in wear, Type of wear- Adhesive, Abrasive, Erosive, Corrosive wear, Factors affecting wear resistance of metals, Analysing wear failure. Case studies**.** (4)

ELEVATED TEMPERATURE FAILURES: Creep, stress rupture, Elevated temperature fatigue, Metallurgical instabilities, and Environmental induced failure. Case studies (4)

FAILURES RELATED TO WELDING AND FAILURES RELATED TO HEAT TREATING OPERATIONS. (4)

FAILURES RELATED TO METALWORKING AND FAILURES RELATED TO CASTING. (3)

RELIABILITY: Reliability concept and hazard function, Life prediction, Condition monitoring, application of Poisson, exponential and Weibull distribution for reliability - bath tub curve - Parallel and series system - mean time between failures and life testing. (5)

Total L: 45

REFERENCES:

1. Colangelo V J and Heiser F A, "Analysis of Metallurgical Failures", John Wiley & Sons, Inc., New York, 1974.
2. Charlie R Brooks and Ashok Choudhury, "Metallurgical Failure Analysis", McGraw Hill Publishing Co., USA., 1993.
3. ASM Handbook, "Failure Analysis and Prevention", Metals Park, Ohio, USA, 1995.
4. Das A K, "Metallurgy of Failure Analysis", Tata McGraw Hill Publishing Co.,New Delhi,1996.

15YN31 ADVANCED MATERIALS

3 0 0 3

INTRODUCTION: Introduction to advanced materials – High and low temperature materials, superconductors, supra magnetic materials, high entropy alloys, biomaterials - their need, advantages and properties (9)

NANOMATERIALS: Introduction-structure and properties of nano materials, carbon nano structures - production methods – physical and chemical synthesis – high energy ball milling-examples. Nano materials for optical, bio, electrical, magnetic, mechanical and structural functions - applications. (9)

METALLIC AND CERAMICS MATERIALS: High strength alloys, intermetallics, quasicrystals, immiscible alloy systems and in-situ composites, metallic glasses, superalloys, single crystals, metallic foams, shape memory alloys-advantages and applications. Refractories, insulators, ceramic matrix composites, dispersion strengthened alloys - their advantages and applications. Thin films, coatings (9)

ADVANCED MATERIALS PROCESSING: Various methods - Mechanical alloying, Rapid Solidification Processing, Melt spinning, atomization techniques, sol-gel, Self Propagating High Temperature Synthesis - processing capabilities - process parameters - examples of material synthesized - Advantages (9)

CONSOLIDATION TECHNIQUES: Consolidation techniques for ceramics and metallic powders - Cold and Hot Isostatic Pressing, Powder extrusion, Equal Channel Angle Process, spark plasma sintering. (9)

Total L: 45

REFERENCES:

1. Metals Handbook, "Powder Metallurgy", ASM Metals Park, Ohio,1991.
2. Nobru H Ichinose, "Introduction to Fine Ceramics", Butterworth-Heinman Ltd, NY, 1992.
3. Reed R C, "The Superalloys: Fundamentals and Applications", Cambridge, 2006.
4. Liebermann H H, "Rapidly Solidified Alloys: Processes, Structure, Properties, Applications", Marcel Dekker,Inc,1993.
5. Brian cantor, "Automotive Engineering: Light weight, functional and novel materials", Taylor and Francis, 1993.
6. Fujiwara T and Ishii Y, "Quasicrystals-Handbook of Metal physics", Elsevier, 2008.

15YN32 MATERIALS MODELING

3 0 0 3

NUMERICALLY SOLVING LINEAR AND NONLINEAR EQUATIONS: Solving set of linear equations-Gauss elimination method, Choleski method, Iterative method, Relaxation method. Roots of non linear equations-Bisection, regula falsi, newton raphson, secnat method. solving system of non linear equations-Newton raphson method. Matlab programmes. (9)

NUMERICALLY SOLVING ORDINARY AND PARTIAL DIFFERENTIAL EQUATIONS AND NUMERICAL INTEGRATION: Numerical integration-Newton-Cotes integration formula, Trapezoidal rule, Simpson's rule, Ranberg's method and Gaussian quadrature. Solving ordinary differential equations, Euler method, Runge kutta 2^{nd} and 4^{th} order methods, and Predictor and corrector methods. Solving partial differential equations. (9)

FUNDAMENTALS OF DISCRETIZATION TECHNIQUE: Fundamentals of finite difference and finite element method. (9)

APPLICATION OF DISCRETIZATION TECHNIQUES IN PROCESS METALLURGY: Modeling of solidification, casting, diffusion and welding. (9)

COMPUTATIONAL PHASE DIAGRAM: Introduction to CALPHAD approach, construction of binary and ternary phase diagrams using CALPHAD approach. (9)

Total L: 45

REFERENCES:

1. Ghoshdastidar P S, "Computer Simulation of flow and heat transfer", Tata McGraw Hill, 1998.
2. Jaan Kiusaalas, "Numerical methods in engineering with MATALAB", Cambridge, 2001.
3. Michel Rappaz, Michel Bellet and Michel Deville, "Numerical Modeling in Materials Science and Engineering", Springer series in computational mathematics, 2003.

15YN33 CREEP, FATIGUE AND FRACTURE

3 0 0 3

CREEP: Creep and stress rupture tests Creep Mechanism, Temperature - Stress-Strain Rate Relationships.

CREEP DEFORMATION MECHANISM: Deformation Mechanism Map, parametric relationships, Life Prediction and Elevated Temperature Failure, Materials for elevated temperature use. (9)

FATIGUE: Cyclic Loading, Cyclic stress and cyclic strain controlled fatigue S-N curve, effect of notch on fatigue life, fatigue crack initiation mechanisms, Macroscopic fracture modes and microscopic fracture mechanisms. (5)

FATIGUE CRACK GROWTH: Predicting Direction of Crack Growth, Fatigue life estimation of notched components, Crack Closure, creep-fatigue interaction, corrosion fatigue, parameters affecting fatigue, Paris law, Fatigue threshold and Fatigue Life estimation. (8)

FRACTURE MECHANICS: The Fracture Mechanics Approach to Design, family tree of fracture mechanics, Effect of Material Properties on Fracture. (3)

LINEAR ELASTIC FRACTURE MECHANICS: Fracture toughness, The Griffith Energy Balance, The Energy Release Rate, Stress Analysis of Cracks, Relationship between K and G, Plane Strain Fracture: Fact vs. Fiction, Mixed-Mode Fracture, and Interaction of Multiple Cracks. (8)

ELASTIC-PLASTIC FRACTURE MECHANICS: Crack-Tip-Opening Displacement. The J Contour Integral, Relationships between J and CTOD, J-Controlled Fracture, Scaling Model for Cleavage Fracture. Test Procedures for K_{IC}, CTOD & J integral. (8)

FRACTURE MECHANISMS IN METALS AND NON METALS: Ductile Fracture, Cleavage, Intergranular Fracture. Microstructural aspects of fracture toughness. Fracture Mechanisms in Nonmetals : Yielding and Fracture in Polymers, Fiber-Reinforced Plastics , Ceramics and Ceramic Composites . Environment assisted fracture – Overview (4)

Total L: 45

REFERENCES :

1. Dieter G E, "Mechanical Metallurgy", McGraw hill Book Company, 2001.
2. "Fracture Mechanics Metals Handbook", American Society of Metals Metal Park Ohio, 1985.
3. Hertz berg R W, "Deformation and fracture mechanics of Engineering materials", John wily sons inc, New York, 1983.
4. Knott J F, "Fundamentals of Fracture Mechanics", Bullerworth London, 1973.
5. Prashant Kumar, "Elements of Fracture Mechanics", McGraw Hill Education (India) Private Limited, 2009.

15YN34 WELDING PROCEDURES AND QUALIFICATIONS

3 0 0 3

PROCESSES: Equipment, power sources, electrical polarities, process variables and consumable selection related to the arc welding processes: Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW), Flux Cored Arc Welding (FCAW) and Submerged Arc Welding (SAW). (5)

CONSUMABLES: AWS Specifications for Electrodes / Filler metals for carbon steels, low alloy steels, high chromium steels, stainless steels, cast irons, aluminium alloys, nickel alloys, copper alloys, titanium alloys hard facing alloys. Compositional ranges, mechanical and other properties and filler metal qualifications. Classification as per ASME B&PV Code Section IIC. (5)

WELDING METALLURGY: Physical metallurgy of carbon steels, low alloy steels, high chromium steels, stainless steels, cast irons, aluminium alloys, nickel alloys, copper alloys, titanium alloys and hard facing alloys. Metallurgical difficulties in arc welding of these alloys, causes and remedial methods. (5)

WELDING PROCEDURE SPECIFICATIONS: Welding Procedure requirements as per ASME B&PV IX, AWS D1.1 and API 1104. Preparation of Welding Procedure Specifications as per ASME B&PV IX for joining of carbon steels, low alloy steels, high chromium steels, stainless steels, aluminium alloys, nickel alloys, copper alloys and titanium alloys, using SMAW, GTAW, GTAW+SMAW, SAW, SMAW+SAW and GTAW+SMAW+SAW, for varying values of thickness ranges, post weld heat treatment conditions and filler metals. Preparation of Welding Procedure Specifications for weld overlay of stainless steels, nickel alloys and copper alloys over low carbon steel and low alloy steel base metals. (20)

PROCEDURE QUALIFICATIONS: Qualification of Welding Procedures for butt welding, fillet welding and weld overlay. Range qualified for various values of Essential variables. Testing for procedure qualifications. Preparation of Procedure Qualification Records. (5)

WELDER PERFORMANCE QUALIFICATIONS: Welder Performance Qualification as per ASME B&PV IX. Testing of welded specimens for performance qualification. Preparation of Welder Performance Qualification records. Range qualified for various vales of essential variables. Performance qualification for fillet welding, butt welding and weld overly. (5)

Total L: 45

REFERENCES:

1. ASM Metals Hand Book, "Welding Brazing and Soldering", 1993.
2. Sindo Kou, "Welding Metallurgy", John Wiley & Sons, 2003.
3. "ASME Boiler & Pressure Vessel Code Section IIC", ASME International, 2015.
4. "ASME Boiler & Pressure Vessel Code Section IX", ASME International, 2015.
5. API Standard 1104, "Welding of Pipelines and Related Facilities", American Petroleum Institute, 2013.
6. AWS D1.1, "Structural Welding Code", American Welding Society, 2010.

15YN35 RESEARCH METHODOLOGY

3 0 0 3

RESEARCH METHODOLOGY: Definition, mathematical tools for analysis, Types of research, exploratory research, conclusive research, modeling research, algorithmic research, Research process- steps. (5)

DATA COLLECTION METHODS: Primary data – observation method, personal interview, telephonic interview, mail survey, questionnaire design. Secondary data- internal sources of data, external sources of data. (6)

SCALES: Measurement, Types of scale – Thurstone's Case V scale model, Osgood's Semantic Differential scale, Likert scale, Q- sort scale. (5)

SAMPLING METHODS: Probability sampling methods – simple random sampling with replacement, simple random sampling without replacement, stratified sampling, cluster sampling. Non-probability sampling method – convenience sampling, judgment sampling, quota sampling**.** (6)

HYPOTHESES TESTING: Testing of hypotheses concerning means (one mean and difference between two means -one tailed and two tailed tests), Concerning variance – one tailed Chi-square test**.** (6)

NONPARAMETRIC TESTS: One sample tests – one sample sign test, Kolmogorov- Smirnov test, run test for randomness, Two sample tests – Two sample sign test, Mann- Whitney U test, K-sample test–Kruskal Wallis test (H-Test**)** (6)

INTRODUCTION: Disciminant analysis, Factor analysis, cluster analysis, multidimensional scaling, conjoint analysis. (6)

REPORT WRITING: Types of report, guidelines to review report, typing instructions, oral Presentation. (5)

Total L: 45

REFERENCES:

1. Kothari C R, "Research Methodology-Methods and techniques", New Age Publications, New Delhi, 2009.
2. Panneerselvam R, "Research Methodology", Prentice-Hall of India, New Delhi, 2004.

15YN36 QUALITY SYSTEM MANAGEMENT

3 0 0 3

FOUNDATIONS OF TQM: Understanding quality, quality, competitiveness and customers, building quality chains, managing quality, quality in all functions, models and frame works for total quality management, Early TQM frameworks - quality award models - the four Ps and three Cs of TQM - a new model for TQM. (6)

LEADERSHIP AND COMMITMENT: The TQM approach - commitment and policy - creating or changing the culture - effective leadership - excellence in leadership. (4)

DESIGN FOR QUALITY: Design, innovation and improvement - the design process - quality function deployment (QFD) - the house of quality - specifications and standards - design in the service sectors - failure mode effect and criticality analysis (FMECA) - The links between good design and managing the business. (5)

PROCESS REDESIGN / ENGINEERING: Reengineering the organization - process for redesign - the redesign process - the people and the leaders. (5)

HUMAN RESOURCE MANAGEMENT: Introduction - strategic alignment of HRM policies - effective communication - employee empowerment and involvement - training and development - teams and team work - review, continuous improvement and conclusions - organizing people for quality - quality circles or kaizen teams. (6)

COMMUNICATIONS, INNOVATION AND LEARNING: Communicating the quality strategy - communicating the quality message - communication, learning, education and training - a systematic approach to education and training for quality - turning educations and training into learning - the practicalities of sharing knowledge and learning. (7)

IMPLEMENTING TQM: TQM and the management of change - planning the implementation of TQM - sustained improvement. (5)

QUALITY AND ENVIRONMENTAL MANAGEMENT SYSTEMS: Benefits of ISO registration - ISO 9000 series of standards - sector specific standards - ISO 9001 requirements - implementation - documentation - writing the documents - internal audits - registration - ISO 14000 series standards - concepts of ISO 14001 - requirements of ISO 14001 - benefits of EMS - integrating ISO 14000 with ISO 9000 - relationship between health and safety. (7)

Total L: 45

REFERENCES:

1. Besterfield D H et al, “Total Quality Management”, Pearson Education Private Limited, 2004.
2. Oakland J S, “Total Quality Management - Text with Cases”, Butterworth - Heinemann - An Imprint of Elseiver, First Indian Print, 2003.

15YN37 CERAMICS PROCESSING TECHNOLOGY

3 0 0 3

POWDER METHODS: Powder preparation by mechanical methods,mechano-chemical synthesis. Powder synthesis by chemical methods – solid state reaction, liquid solutions, vapour phase reactions, combustion synthesis - Synthesis of nano scale ceramic powders- liquid solution techniques, vapor phase techniques. Influence of particle size on packing, microwave synthesis. (7)

PRECIPITATION METHODS: Evaporation; precipitation; Solution growth; Nucleation; Rate of crystallization; Superstaturation; Top seeded solution growth; sol-gel techniques; high temperature solution; Hydrothermal; Solvothermal methods; Ammonothermal method; Glycothermal; Melt methods- super cooling-factors influencing the production of the above methods. (8)

VAPOUR PHASE METHODS: Vapour phase methods - Thin films, epitaxial growth, carrier gases, metastable growth of materials. Chemical Vapour Deposition - Principles, apparatus, examples of CVD growth of thin films, advantages and disadvantages. (10)

FORMING: Forming of ceramics – dry and semi-dry pressing - die compaction and cold isostatic compaction; casting methods - slip casting, pressure casting, gel casting, electrophoretic deposition; Plastic forming methods - extrusion, co-extrusion, injection molding, solid free form fabrication - Porous ceramic forming-intrusion, organic additives – advanced composite manufacture – chemical vapour impregnation(CVI), polymer impregnation followed by pyrolysis(PIP). (10)

SINTERING: Solid state sintering – driving force, effect of surface curvature and boundary defects, mechanism, stages of sintering. Liquid phase sintering – stages, kinetic and thermodynamic factors, phase diagram in liquid phase sintering. Grain growth – different grain growth processes, control of grain growth, grain growth and pore evolution in a porous compact, interaction between pore and grain boundary. Pressure assisted sintering – hot pressing and hot iso-static pressing. Reaction bonding and microwave sintering. (10)

Total L: 45

REFERENCES:

1. Mohamed N.Rahaman, Ceramic Processing, Taylor & Francis, 2007.
2. David W. Richerson, Modern Ceramic Engineering, 3rd Edn., Taylor & Francis, 2005.
3. Paul De Garmo E, Black J.J and Ronald A.Kohser, Materials and Processes in Manufacturing, 8th Edn., Prentice – Hall India
4. Pvt. Ltd., New Delhi, 1997.
5. Reed J.S, Introduction to the Principles of Ceramic Processing, Wiley, New York, 1988.

15YN38 ADVANCED COATING TECHNOLOGIES

3 0 0 3

ELECTROCHEMICAL TECHNIQUES: Chemical conversion coatings, phosphating, chromating, chemical colouring,nodizing of aluminium alloys, deposition of copper, zinc, nickel and chromium - principles and practices, alloy plating, Electrodeposition- Electrocomposite plating. (7)

HIGH PERFORMANCE COATINGS: Thermal spray- Plasma spray-HVOF- D Gun, laser cladding, diffusion coatings, Overlay Coatings. (10)

THIN FILM COATINGS: Chemical Vapour Deposition, Physical Vapour Deposition- Electron Beam- Physical Vapour Deposition, Pulsed Laser Deposition, Sputtering- magnetic sputtering, Electron beam evaporation, Diamond Like Coatings (DLC). (10)

SOLUTION BASED COATING TECHNIQUES: Slurry coating - dip coating, spin coatings, spray coating – spray pyrolysis and cladding, Specific Industrial applications. (8)

COATING CHARACTERIZATION TECHNIQUES: Surface modification – wear, abrasion, oxidation resistance. Coatings – measurement of coating thickness-porosity-hardness, fracture toughness, elastic modulus – adhesion-bending strength-fracture strength- tensile strength, coating tribology, corrosion measurement, phase analysis and microstructural evaluation. (10)

Total L: 45

REFERENCES:

1. Lech Paw Lowski , Science and engineering of thermal spray coatings, John wiley and sons Inc., 1999
2. Klein, L., (Ed), Sol-Gel Technology for Thin Films, Fibres, Performs, Electronic and Speciality Shapes, 1988, Noyes Publications, New Jersey, USA.
3. Bunshah.R.F. (Ed), Films and Coatings for Technology, Noyes Date Corp., New Jersey, USA,1982.
4. Sudarshan T S, 'Surface modification technologies - An Engineer's guide', Marcel Dekker, Newyork, 1989

15YN39 HIGH PERFORMANCE CERAMICS

3 0 0 3

MICROSTRUCTURAL ANALYSIS: Quantitative analysis of texture, nature of grain boundaries, development of microstructure, grain growth, effect of particle size, pressure and sintering, dependence of mechanical and thermal properties on microstructure of glass ceramics. (8)

EVALUATION OF STRUCTURAL CERAMICS: Fracture behaviour of ceramic materials, Weibull distribution, Toughening mechanisms. Formation, mechanical property and evaluation of fused alumina, sintered alumina products, borides, carbides, nitrites, silicides, zirconia and partially stabilized, zirconia, SIALON (10)

MECHANICAL PROPERTIES AT ROOM TEMPERATURE: Elastic modulus, tensile and flexural strength, hardness, fatigue, fracture, wear, mechanical shock. (6)

PROPERTIES AT ELEVATED TEMPERATURES: Thermal expansion, thermal conductivity, thermal shock resistance, creep and oxidation. (6)

CERAMICS & COMPOSITES FOR HOSTILE ENVIRONMENTS: Ceramic materials for wear resistance, cutting tool, IC engine, gas turbine, material selection for Infra red window materials, lamp envelops, chemical degradation, nuclear waste storage materials, nuclear fuels and fuel cell, ceramic membranes, ceramic armours. Heat engine ceramics – turbine blade ceramics – heat exchanger ceramics –heat shield ceramics – composites-metal matrix , polymer matrix, ceramic matrix composites. (15)

Total L: 45

REFERENCES:

1. Richardson D.W., "Modern Ceramic Engineering Properties", Processing and Use in Design, 1992, Marcel Dekker, New York.
2. Howlettt, S.P. and D.Taylor (Ed), "Special Ceramics", Vol.8 1986, The Institute of Ceramics Shelton, Stock On-Trent, Staff,UK.
3. Wachtmen, J.B.,"Structural Ceramics, Treatise on Materials Science and Technology", Vol.29, 1989, Academic Press Inc, NY.
4. Mellinger, G.B., "Nuclear Waste Management 3, Ceramic Transactions", Vol.9., 1990, The American Ceramic Society Inc.,
   Westerville, Ohio, USA.
5. Larsen D.C., Adams C.W., Johnson L.R, Teotia A.P.S. and L.G.Hill, "Ceramic Materials for Advanced Heat Engines", 1985, Noyes Pub., New Jersey, USA.

15YN40 HIGH TEMPERATURE BEHAVIOUR OF ALLOYS AND CERAMICS

3 0 0 3

MECHANICAL BEHAVIOUR OF MATERIALS: Elevated temperature characteristics of engineering materials for high temperature applications and problems associated with the use of materials at high temperatures, Plasticity, Strengthening mechanisms in materials, Fatigue, Creep at elevated temperatures. (6)

DEFORMATION MECHANISMS: Factors influencing the functional life of components at elevated temperature, Various types of fracture, brittle to ductile from low temperature to high temperature, cleavage and ductile fracture (microvoid coalescence - diffusion controlled void growth) fracture maps for different alloys and oxides. (7)

MATERIALS AND IPROCESSING TECHNIQUES: Iron base, nickel base and cobalt base superalloys, composition control, solid solution strengthening, precipitation hardening,grain boundary strengthening, TCP phase - embrittlement, solidification of single crystals , Refractory metals, alloys and Structural inter-metallics, Structural ceramics- types, applications, properties, processing. Carbon-Carbon composites,processing, properties. (10)

OXIDATION AND CORROSION BEHAVIOUR: Oxidation and hot corrosion -Oxidation, Pilling Bedworth ratio, kinetic laws of oxidation – defect structure and control of oxidation by alloying, effect of alloying elements on hot corrosion behavior, interaction of hot corrosion and creep, High temperature corrosion of carbon steels, alloy steels, stainless steels and super alloys. (10)

PROTECTIVE COATINGS: Coatings - Processes for the deposition of coatings on the superalloys, Thermal barrier coatings, Overlay coatings and Diffusion coatings. Thermal barriers in space vehicles and satellites. (5)

CHARACTERIZATION OF SURFACE AND COATINGS: Surface Characterization (physical and chemical methods, XPS, AES, RAMAN, FTIR, Structural Characterization, Mechanical Characterization (Adhesion, Hardness, Elastic Properties, Toughness, Fracture toughness, Scratch and Indentation, Wear type and Characterization, wear surface analysis, Tribometer, Friction, Low friction materials/coating, Corrosion testing. (7)

Total L: 45

REFERENCES

1. Newkirk J B, High temperature materials, Frederick muller Ltd.,1980.
2. David L Price,High temperature levitated materials, Cambridge university Press P.Ltd, 2010.
3. DonachieM , Super alloys,American showcase Inc.,1984.
4. Kaibyshev O A,Superplasticity of alloys Intermetallides and Ceramics,Springer Verlag ,1992.
5. Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Wiley & Sons (2008).

15YN41 ALLOY DESIGN

3 0 0 3

INTRODUCTION: Concept of alloy design, Steps in alloy design, Significance of alloy design. (2)

ALLOY PROPERTIES AND EFFECTS: Single phase, dual phase and multiphase materials, Effect of matrix on properties of materials, Effect of size, shape and distribution of second phase on mechanical properties of alloys (4)

DESIGN OF ALLOYS: Alloy design for better tensile strength, ductility, toughness, fatigue strength, creep strength, wear resistance and elevated temperature strength. Summary of design principles. (4)

PHASE TRANSFORMATIONS : Precipitation and particle coarsening, recrystallization and grain growth. Solid/Liquid phase transformation in pure metals, single phase alloys, constitutional supercooling and eutectic alloys. Composite Strengthening -Introduction , Fabrication - Principles of Fiber Reinforcement ,Applications of Strengthening Methods in Commercial Alloys (10)

CREEP RESISTANCE : Introduction - Microstructure and Creep Resistance - Dynamic Micro structural Changes and Creep Resistance - Environments and Creep Resistance - Creep Crack Growth Resistance – Alloy design for creep . (6)

STRESS RUPTURE RESISTANCE : Introduction -Methods of Achieving Increased Stress Rupture Resistance with Cobalt-Base Alloys - Examples of Cobalt Alloy Development for Stress Rupture Resistance -Methods of Achieving Increased Stress Rupture Resistance with Nickel-Base Superalloys -Example of Nickel Alloy Development for Stress Rupture Resistance - Controlled Solidification - Prealloyed Powder - Statistical Methods - Alloy Design for Increased Stress Rupture Resistance. (10)

APPLICATIONS : Alloy design of lightweight and high strength powder metallurgical Al based alloys; Ni Base alloys, Co base alloys High strength low alloy steels. (7)

APPLICATION OF COMPUTER-BASED METHODS FOR ALLOY DESIGNING. (2)

Total L: 45

REFERENCES:

1. ASM Hand Book, “Properties and Selection”, Vol 1 and 2, ASM, Metals Park, Ohio, 2008.
2. Tien John K., Ansell George S. “Alloy and Microstructural Design”, Academic Press, Elsevier Science, 1976.
3. ASM Hand Book “Materials Selection and Design”,Vol 20, Metals Park, Ohio. 1993.
4. Ashby M F, “Materials Selection in Mechanical Design”, Butterworth- Heineman, New York, 2005.
5. Ranganathan S., Arunachalam V.S. , Cahn R.W. “Alloy Design”- Indian Academy of Science, Bangalore, 1981

15YN42 SEMI SOLID METAL CASTING AND FORMING PROCESSES

3 0 0 3

INTRODUCTION: Introduction, Rheology and Thixotropy, difference between conventional casting and semi solid metal casting processes, physical metallurgy of semi solid casting alloys, advantages, applications, semi solid material processing technologies. (7)

SLURRY PROCESSING: Semi solid material delivery system, vertical induction slug heating, horizontal induction slug heating, horizontal convection slug heating, direct slurry production (Rheo casting/ Thixo moulding), direct slurry forming, semi solid slugs from slurry. (7)

THIXO PROCESSES: Thixo casting and forming mechanism, methods, Mould and die preparation, machines, materials, advantages, disadvantages, and applications. (7)

RHEO PROCESSES: Rheo casting and forming mechanism, Mould and die preparation, furnaces, methods, machines, die casting materials, advantages, disadvantages, and applications. (8)

SQUEEZE CASTING /LIQUID FORGING: Direct squeeze casting, Indirect squeeze casting, machines, Horizontal-die-clamping Vertical-shot Squeeze Casting machine, Vertical-die-clamping Vertical-shot Squeeze Casting machine, advantages, disadvantages and applications. (8)

SPECIAL SEMI SOLID PROCESSES: Mechanical stirring, Magneto Hydrodynamic stirring (MHD), Non agitation: Cooling Slope casting. Solid route - Strain Induced Melt Activated (SIMA), Recrystallisation and Partial Melting (RAP), Direct Partial Remelting (DPRM) (5)

SIMULATION AND MODELING METHODS FOR SEMI SOLID CASTING (3)

Total L: 45

REFERENCES:

1. David H. Kirkwood, Michel Suéry, Platon Kapranos, Helen V. Atkinson, Kenneth P. Young "Semi-solid Processing of Alloys" Springer Science & Business Media, 2009.
2. Shahrooz Nafisi, Reza Ghomashchi " Semi-Solid Processing of Aluminum Alloys" Springer, 2016.
3. Anacleto de Figueredo "Science and technology of semi-solid metal processing "North American Die Casting Assoc., 2001.

15YN43 PROCESSING OF ALUMINIUM ALLOYS

3 0 0 3

CLASSIFICATION OF ALUMINIUM ALLOYS: Cast and wrought alloys- Temper designation systems – Physical metallurgy of Aluminium alloys. Solidification structures of Aluminium alloy Ingots - Microstructures of aluminium wrought Aluminium alloys - Microstructures of Cast alloys. Control of Hydrogen, Inclusions and grain size during DC casting. (10)

CASTING OF ALUMINIUM ALLOYS: Solid state, Liquid state, Spray Deposition Processes, Direct chill (DC) casting of various aluminium alloys. (8)

SEMI-SOLID PROCESSING OF ALUMINUM ALLOYS: Thixocasting, rheocasting and thixomolding (4)

FORMING OF ALUMINIUM ALLOYS: Forging methods (Open die, closed die and rolled rings) – Cold and Hot Extrusions – Sheet/plate rolling of various aluminium alloys. Equal-Channel Angular Pressing (ECAP), Cold Forming, Warm Forming, Hot Stamping. (5)

WELDING OF ALUMINIUM ALLOYS: Various welding process, Microstructure and mechanical characteristics of Aluminium weldments. (5)

HEAT TREATING OF VARIOUS ALUMINIUM ALLOYS (Annealing-Solutionising-Ageing) and the related strengthening mechanisms- Heat treatment furnaces used for Aluminium alloy products. Cleaning, finishing and coating. (10)

Tribological behavior of various Aluminium alloys. (3)

Total L: 45

TEXT BOOKS:

1. ASM Specialty hand book – "Aluminium and Aluminium alloys" –ASM International; Materials Park, 2010.
2. Sheppard.T,"Extrusion of Aluminium alloys" – Springer science, 2013.
3. ASM Handbook "Aluminium – Volume – I: Properties, Physical Metallurgy and Phase diagrams" - ASM Metals Park, Ohio, USA,1967.
4. ASM Handbook "Aluminium – Volume – II: Design and Applications" - ASM Metals Park, Ohio, USA, 1967.
5. ASM Handbook "Aluminium – Volume – III: Fabrication and Finishing" - ASM Metals Park, Ohio, USA, 1967.

. 15YN44 WELDING CODES AND STANDARDS

3 0 0 3

PROCESSES & WELDING METALLURGY: Selected welding processes: SMAW, GTAW, GMAW, FCAW, SAW - Equipment, Welding parameters, Electrodes / Filler metals Classifications as per AWS. Welding metallurgy of selected metals – Carbon steels, low alloy steels, stainless steels, Ni alloys, Cu alloys, Al alloys . (9)

CODE PRACTICE: Familiarization of codes: Sections IIC and IX of ASME B&PV Code, API 1104 and AWS D1.1; Essential variables, Non-essential variables, Supplementary essential variables WPS formats, PQR formats and WPQ formats Test requirements; Range qualified for varying values of essential values. Preparation of WPSs, PQRs and Range Qualified tables; Preparation of WPQs. (9)

WELDING PROCEDURE SPECIFICATIONS (WPS) – FERRITIC STEELS: Preparation of WPS's for metal joining for Process variation: SMAW, GTAW, GTAW+SMAW, GMAW, SAW, SMAW+SAW, GTAW+SAW Material variation: Carbon steels, Low Alloy Steels, Cr-Mo Steels Post Weld Heat Treatment: No PWHT, Stress Relieving, Other Heat Treatments Thickness: 2 to 200 mm. Totally about 75 WPSs to be prepared under this category. (9)

WELDING PROCEDURE SPECIFICATIONS (WPS) – STAINLESS STEELS AND NON-FERROUS ALLOYS: Preparation of WPS's for metal joining for Process variation: SMAW, GTAW, GTAW+SMAW, GMAW, SAW, SMAW+SAW, GTAW+SAW Material variation: Stainless steels, Nickel alloys, Copper alloys, Titanium alloys, Al Alloys. Preparation of WPS's for dissimilar metal joining for Process variation: SMAW, GTAW+SMAW Material combination: Carbon steel to low alloy steels, Stainless steels to carbon steels, Copper alloys to carbon steels, Low alloy steels to another low alloy steel.Preparation of WPS's for weld overlaying of Stainless steels over carbon steel, Nickel alloys over carbon steels, Cu alloys over carbon steels, Stellite over carbon steels / stainless steels. Totally about 75 WPSs to be prepared under this category. (9)

PQRS AND WPQS: Preparation of PQRs for selected WPSs. Preparation of WPQs for selected WPSs for various processes, material thicknesses, positions for butt welding, fillet welding and weld overlay. Totally about 25 PQRs to be prepared for WPSs for butt welding, fillet welding and weld overlay. (9)

Total L: 45

REFERENCES:

1. ASM Metals Handbook, ,"Welding Brazing and Soldering", Vol 6,ASM International, 2003.
2. ASME B&PV Code Section IX and Section IIC
3. API Code 1104: Welding of pipelines and related facilities.
4. AWS code D1.1 Structural welding – steel.

15YN45 WELDING CONSUMABLES

3 0 0 3

FLUX COATED ELECTRODES: SMAW electrodes for carbon steels, low alloy steels, stainless steels, Al alloys, Cu alloys, Ni alloys – Classification as per AWS, Requirements of mechanical properties, chemical composition, testing requirements, intended use of important electrodes Problems based on selection of flux coated electrodes based on flux characteristics, material to be welded, properties required / applications. Filler metal qualification as per Section IIC. (9)

BARE WELDING ELECTRODES AND RODS: Bare welding electrodes and rods for carbon steels, low alloy steels, stainless steels, Al alloys, Ni alloys, Cu alloys, Ti alloys– Classification as per AWS, Requirements of mechanical properties, chemical composition, testing requirements, intended use of important electrodes.Problems based on selection of bare welding electrodes and rods based on material to be welded, properties required / applications. Filler metal qualification as per Section IIC. (9)

ELECTRODES AND FLUXES FOR SAW AND FLUX CORED ELECTRODES: SAW electrodes for carbon steels, low alloy steels, Fluxes, manufacturing methods, chemical nature; FCAW electrodes for Carbon steels, Low alloy steels, Stainless steels, Ni alloys.

Classification as per AWS, Requirements of mechanical properties, chemical composition, testing requirements, intended use of important electrodes. Problems based on selection of electrodes and fluxes based on flux characteristics, material to be welded, properties required / applications. Filler metal qualification as per Section IIC. (9)

SURFACING ELECTRODES, CAST IRON ELECTRODES AND RODS: Classification as per AWS, Requirements of mechanical properties, chemical composition, testing requirements, intended use of important electrodes Problems based on selection of electrodes / rods based on material to be welded, properties required / applications. Filler metal qualification as per Section IIC. (9)

BRAZING METALS, BRAZING FLUXES, TUNGSTEN ELECTRODES, SHIELDING GASES: Classification as per AWS, intended use, testing requirements, Shielding gases - Types, characteristics, physical properties, shielding properties, applications.

Problems based on brazing metals, brazing fluxes, tungsten electrodes, shielding gases based on material to be joined, properties required / applications. Filler metal qualification as per Section IIC. (9)

Total L: 45

REFERENCE:

1. ASME Boiler and pressure Vessel Code – Part II C – Specifications for Welding Rods, Electrodes and Filler metals, 2013.
2. Larry Jeffus, "Welding principles and applications", Delmer cengage learning, 2012.
3. Lancaster, "Metallurgy of welding", ELS, 2012.
4. Granjon, "Fundamental of welding metallurgy", Abington, 1991.

ONE CREDIT COURSES

For the detailed syllabi of the electives and one credit courses offered by other departments refer to the syllabi of M.E- Automotive Engineering offered by Automobile Engineering Department.