**SYLLABUS**

**FOR**

**SEVENTH SEMESTER**

**METALLURGY**

**SEVENTH SEMESTER**

**MT 010 701 Corrosion Science and Engineering**

**MT 010 702 Non Destructive Testing and Failure Analysis**

**MT 010 703Ceramics, Polymers and Composites Materials**

**MT 010 704Theory of Metal Forming**

**MT 010 705 Powder Metallurgy**

**MT 010 706 Elective - II**

**MT 010 707 Electro-metallurgy Laboratory**

**MT 010 708 Metal Forming Laboratory**

**MT 010 709 Seminar**

**MT 010 710 Project Preliminaries**

**ELECTIVES – II**

**MT 010 706 L01 EMERGING MATERIALS**

**MT 010 706 L02 HIGH TEMPERATURE MATERIALS**

**MT 010 706 L03 SEMICONDUCTING MATERIALS AND DEVICES**

**MT 010 706 L04 ENGINEERING OPTIMIZATION TECHNIQUES**

**MT 010 701 CORROSION SCIENCE AND ENGINEERING**

**Teaching Scheme Credits 4**

3 hours lecture and 1 hour tutorial per week.

**Objectives**

This course is designed to provide the students of metallurgy an updated overview of the essential aspects of corrosion science and engineering and the methods to evaluate, monitor and prevent corrosion industrially. The students are also expected to actively participate in understanding corrosionand solving problems.

**MODULE I**

Introduction- Corrosion engineering, Definition of corrosion, Environments, Corrosion damage, Classification of corrosion, The cost of corrosion.

Corrosion Principles- Introduction, Corrosion Rate Expressions, Electrochemicalaspects, Electrochemical reactions, Polarization, Corrosively and Passivity,Environmental Effects, Effects of Oxygen and Oxidizers, velocity, Temperature, Corrosive concentration, Galvanic coupling, Metallurgical and other aspects, Metallic properties, Economic considerations.

Theory of corrosion-Causes of corrosion- Change in Gibbs free energy, Pilling–Bedworth Ratio. The dry-cell analogy and Faraday’s law, definition of Anode and Cathode, Types of cells, Freeenergy, Change of Gibbs Free Energy Cell Potentials and the EMF Series ,Convention of Signs and Calculation of Emf, Measuring the Emf of a Cell, Calculating the Half-Cell Potential—The Nernst Equation, The Hydrogen Electrode and the Standard Hydrogen Scale,Liquid junction potential, Reference electrodes, Applications of Thermodynamics to Corrosion,Pourbaix diagrams, Electrode Kinetics Exchange Current Density, Activation Polarization, Concentration Polarization, Combined Polarization, Mixed-Potential theory, Mixed Electrodes, Passivity, Mechanisms of the Growth and Breakdown of Passive Films.

**MODULE II**

Forms of corrosion- Basics of galvanic, crevice, pitting, inter granular,weld decay, knife line attack, erosion and stress corrosion, corrosion fatigue, fretting corrosion, Damage due to hydrogen- characteristics, environmental factors, blistering, embrittlement, fracture mechanics. Selective leaching- dezincification, graphitization, other metallurgical influence.

Fundamentals of corrosion under various environments- Corrosion of various metals and alloysin mineral acids. Atmospheric corrosion. Corrosion in aqueous medium- corrosion in Seawater, Fresh Water, High-Purity Water.High temperature corrosion- Introduction, Initial Stages, Thermodynamics of Oxidation: Free Energy–Temperature Diagram,Protective and non-protective scales , Wagner Theory of Oxidation, Oxide Properties and Oxidation , Galvanic Effects and Electrolysis of Oxides ,Hot Ash Corrosion, Hot Corrosion, Oxidation of Copper, Internal Oxidation, Reaction with Hydrogen, Oxidation of Iron and Iron Alloys.Rudiments of molten salt corrosion, liquid metal corrosion,corrosion by gases, microbiological corrosion, corrosion in soils.

**MODULE III**

Corrosion testing -Importance, methods and monitoring- Introduction. Corrosion maintenance through inspection and monitoring. Design planning and preparing corrosion tests. Weight loss. Electrochemical methods. Cabinet testing. Aeration. SSRT,Standard expression for corrosion rate. Tests for stainless steels.Warren test. NACE and slow strain rate test methods. Simulation service testing under atmosphere, in water and in soil. Evaluating Pitting, crevice, galvanic, intergranular, exfoliation and stress corrosion, hydrogen embrittlement, corrosion fatigue.Evaluation of influence of microbiological and gaseous environments. Paint, sea water tests. Presenting and interpretation of results.

**MODULE IV**

Corrosion protection methods- Introduction. Fundamentals of corrosion protection in aqueous solution. Protective coatings- Surface preparation, Hot dip and conversion ( chromate and phosphate ) coatings, Electrodeposition, Anodising, CVD/PVD coatings. Thermal spraying. Cathodic and anodic protection. Inorganic and organic coatings. Inhibitors and passivators.

**MODULE V**

Corrosion and protection of specific alloy systems - Carbon steels, Alloy steels, stainless steels, Cast irons and steels, Al, Cu, Mg, Ti, Ni, Co, Zn, Sn, Be, Nb, Zr,Ta ,alloys , noble metals , cemented carbides, MMCs, braze joints.

Designing to reduce corrosion, modeling life prediction, prediction of service life of structures, analytical equipments for a corrosionist. Examples of industrial corrosion failures-typical examples of failures due to corrosion from different industrial environments, body implants.Corrosion for constructive purposes-electropolishing, electrochemical machining, electrochemical refining, chemical-mechanical planarization.

**Text books**

1. Corrosion Engineering- Mars.G.Fontana, McGraw Hill, New York.
2. Corrosion and Corrosion Control- R. Winston Revie,Herbert H. Uhlig, John Wiley & sons, Inc.,New Jersy, 2008.
3. Electrochemistry and corrosion science- Nestor Perez, Kluwer academic publishers , New York, 2004.

**Reference books**

1. Handbook of CorrosionEngineering, Pierre R. Roberge, McGraw-Hill, New York, 1999.
2. Corrosion , Volume 13, ASM International, 1992.
3. Corrosion fundamantals, testing and protection, Volume 13A , ASM International, 2003.
4. Corrosion Science and Technology, David Talbot, James Talbot, CRC New York, 1997.

**MODEL QUESTION PAPER**

**MT 010 701 CORROSION SCIENCE AND ENGINEERING**

**PART A (5 X 3 =15 marks)**

1. Explain the terms mm/y and gmd in corrosion science.
2. What is SCC? What are the three basic conditions for effecting SCC in an alloy?
3. Expand NACE. Explain briefly the NACE test method to evaluate corrosion.
4. Explain “conversion coating”.
5. Taking into account the functions, cost and probable method of manufacture, suggest suitable material for making a) washing machine drums, b) exterior architectural fittings for a hotel facing Arabian Sea and containers for automobile catalytic containers.

**PART B (5 X 5 =25 marks)**

1. Name the three main types of cells that take part in corrosion reactions. Discuss the Concentration cells.
2. Explain “Hydrogen Disease”.
3. Explain the mechanism of passivation.
4. Under what circumstances can cathodic protection (either sacrificial protection or impressed current protection) are used to protect an automobile from corrosion?
5. Explain sensitization in stainless steels.

**PART C (5 X 12 =60 marks)**

1. a) What are reference electrodes? Explain the Calomel electrode.

b)Calculate the half - cell potential of the hydrogen electrode in a solution of pH = 7 and partial

pressure of H2 = 0.5 atm at 40 ° C.

**OR**

12. a ) What is understood by “passivity” of an alloy?

b) The potential of an iron electrode when polarized as cathode at 0.001 A/cm2 is − 0.916 V versus

1*N* calomel half - cell. The pH of the electrolyte is 4.0. What is the value of the hydrogen

over-potential?

13**.** a) Explain “hot ash”corrosion.

b) Calculate *Md*/ *nmD*for aluminum forming Al2 O3 and for sodium forming Na2O. Indicate whether

the oxides are protective.

**OR**

14.a)Explain the mechanism of Hydrogen damage.

15. How is the pitting corrosion evaluated?

**OR**

16**.** Explain the evaluation of Hydrogen Embrittlement of alloys.

17. Explain the basics of anodic and cathodic protection of metallic materials from corrosion. Compare the processes.

**OR**

18. Briefly describe the vapour deposition processes for corrosion protection.

19. How can you explain corrosion of metals and alloys for constructive purposes? Explain with suitable examples.

**OR**

20. A valve body , machined out of Al-Znalloyextrusion and anodized and having sharpinternalcorners, was found to develop cracks inside when put into service . The valve body was in contact with a corrosivemedium. What is the most probable reason for the premature failure of this valve body? Give reasons for your conclusion. Necessary sketches may be given to support your arguments.

**MT 010 702 NON DESTRUCTIVE TESTING AND FAILURE ANALYSIS**

**Teaching Scheme Credits 4**

3 hours lecture and 1 hour tutorial per week.

**Objectives**

This course is designed to provide the students of metallurgy basic knowledge of the non destructive methods to evaluate the soundness of metallic products in semi or finished conditions. It also gives an insight to the types and causes of metallurgical failures of semi finished components during their production and finished components in service or in storage. The course also gives methods to prevent the recurrence of such failures

**MODULE I**

What is NDT, Comparison between destructive testing and NDT, importance of NDT, scope of NDT, difficulties of NDT, future progress in NDT, economic aspects of NDT.

**Visual Inspection**: Tools, applications and limitations, Fundamentals of visual testing, vision, lighting and material attributes, environmental factors, visual perception, direct and indirect methods, mirrors, magnifiers, boroscopes, fibroscopes, closed circuit television, light source and special lighting, computer enhanced systems.

**Liquid Penetrant Inspection (LPI)**: Principles, properties required for a good penetrant and developers, Types of penetrants and developers, advantage and limitations of various methods og LPI, LPI techniques, test procedures, interpretation and evaluation of penetrant test indications, false indication, safety precautions required in LPI applications, advantages and limitations.

**Magnetic Particle Inspection(MPI**): Principles of MPI, basic physics of magnetism, permeability, flux density, cohesive force, magnetizing force, retentivity, residual magnetism, Methods of magnetization, Magnetization techniques such as head shot technique, cold shot technique, central conduction testing, magnetization using products, using yokes, direct and indirect method of magnetization, continuous testing of MPI, residual testing of MPI, system sensitivity, checking devices in MPI, interpretation of MPI indications, advantage and limitations of MPI.

**MODULE II**

**Ultrasonic Testing (UT**): Principle, type of waves, frequency, velocity, wavelength, reflection, divergence, attenuation, mode conversion in ultrasonics. UT testing methods – contact testing and immersion testing, normal beam and straight beam testing, angle beam testing, dual crystal probe. Ultrasonic Testing Techniques – Resonance testing, Through transmission technique, Pulse echo testing technique. Instruments used in UT, Accessories such as transducers, types, frequencies and size commonly used, reference blocks with artificially created defects, calibration of equipment, applications, advantages and limitations, A,B and C scan-time of flight diffraction , Acoustical Holography- Principles, types, applications, advantage and limitations.

**MODULE III**

**Radiography Testing (RT)**: Principle, electromagnetic radiation sources, X-ray sources, Production of X-rays, High energy X-ray source, Gama ray source, Properties of X-rays and gamma rays, Inspection techniques like SWSI, DWSI, DWDI, Panoramic exposure, real time radiography, types of films, qualities of film, screens used in radiography, quality of a good radiographic film processing, interpretation, evaluation of test results, safety aspects required in radiography, applications, advantages and limitations of RT.

**MODULE IV**

**Eddy Current Testing (ECT)**: Principles, Physics aspects of ECT like conductivity, permeability, resistivity, inductance, inductive reactance, impedance, Filed factor and lift off effect, edge effect, end effect, impedance plane diagram in brief, depth of penetration of ECT, relation between frequency and depth of penetration in ECT, Equipment and accessories, Various application of ECT such as conductivity measurement, hardness measurement, defect detection, coating thickness measurement, advantage and limitations of eddy current testing.

**Thermography**: Principles, Contact and non contact inspection methods- Heat sensitive paints, Heat sensitive papers, Thermally quenched phosphors, liquid crystals, techniques for applying liquid crystals, calibration and sensitivity, Other temperature sensitive coating, non contact thermographic inspection, advantage and limitations, infrared radiation and infrared detectors, Instrumentations and methods, application.

**MODULE V**

**Fatigue Failures:** Statistical nature of fatigue, S-N curve, low cycle fatigue, structural feature of fatigue, fatigue crack propagation, effect of stress concentration, size, surface properties, metallurgical variables on fatigue, case studies, designing against fatigue.

**Wear Failures:** Type of wear, role of friction in wear, lubricated and non-lubricated wear, analysing wear failures.

**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 of analysing stress corrosion cracking, various types of hydrogen damage failures, corrective and preventive action.

**Elevated Temperature Failures:** Creep, stress rupture, elevated temperature fatigue, metallurgical instabilities, environmental induced failure, elevated temperature effects on certain gas turbine components and petroleum refinery components, tests for analysis of failure at elevated temperatures.

**Text Books**

1. Baldev Raj, Practical Non-Destructive Testing, Narosa Publishing House
2. George E Dieter, “Mechanical Metallurgy”, McGraw Hill Book Company

**Reference Books**

1. Hull B and John V. Non-Destructive Testing, McMillan
2. Krautkramer Josef and Hebert Krautkramer, Ultrasonic Testing of Materials, Springer Verlag
3. JaapSchijve, “Fatigue of Structures and Materials”, Kluwer Academic Publishers, 2001.
4. ASM Metals Handbook, "Failure Analysis and Prevention", ASM Metals Park, USA, Vol. 10
5. Richard W Hertzberg,“Deformation and Fracture Mechanism of Engineering Materials”,John Wiley & Sons,Inc.,1995.

**MODEL QUESTION PAPER**

**MT 010 702 NON DESTRUCTIVE TESTING AND FAILURE ANALYSIS**

**PART A (5 X 3 =15 marks)**

1. Name the materials which can be tested by Magnetic particle testing?
2. Define acoustic impedance.
3. What are the basic ways to control the exposure when working with radiographic source?
4. What are the basic factors affecting in thermal measurements?
5. Explain macro and micro features of Ductile fracture

**PART B (5 X 5 =25 marks)**

1. Write a note on eye in visual testing?
2. Explain shear waves in ultrasonic testing? What are its limitations?
3. Explain the double wall single image technique used in Radiographic tests?
4. What is the standard depth of penetration in Eddy current testing?
5. Explain three stages of fatigue failure. Differentiate between striations and beach marks.

**PART C (5 X 12 =60 marks)**

1. Explain the importance of cleaning before and after the Penetrant tests?

**OR**

1. Explain the principle of Magnetic particle testing?
2. Explain the characteristic of ultrasonic beam?

**OR**

1. What is Holography? What are its advantages?
2. What are the radiation monitoring equipments used in Radiographic testing?

**OR**

1. (a) What made the scientists to use Radio graphical methods for NDT? (b) What is the principle of Radio graphical method? (c) What are the sources used for NDT and briefly explain about the two major sources used for industrial applications.
2. (a) In what way eddy current inspection and magnetic inspection differs from each other. (b) Discuss about the use of inspection coils in eddy current inspection system.

**OR**

1. (a) State Faraday’s law of electromagnetic induction. (b) Explain how the flux leakage can be used to find the defects in a specimen.
2. Explain the mechanism of stress corrosion cracking in alloys. Mention the most prominent combination of metals and environments which can lead to stress corrosion cracking.

**OR**

1. (a) Define hydrogen embrittlement of steel. Explain the mechanism of hydrogen induced cracking in the steels. (b) Define wear & explain the mechanism of grinding wear, abrasive wear, gouging wear, and fretting wear.

**MT 010 703 CERAMICS, POLYMERS AND COMPOSITES MATERIALS**

**Teaching Scheme Credits 4**

3 hours lecture and 1 hour tutorial per week.

**Objectives**

To provide the students of metallurgy basic concepts of composite, polymer and ceramic materials, their preparation, applications and qualification.

**MODULE I**

Composite materials. Introduction – Definition, General Characteristics, Applications, Material Selection Process. Materials – Fibers Glass,Carbon, Aramid Fiber Extended Chain Polyethylene, Natural, Boron and Ceramic Fibers. Comparison of fibre strengths. Matrix- Properties. Wettability fibre with matrix – Effect of surface roughness – Interfacial bonding. Polymer Matrix - Thermoplastic and Thermoset Polymers, Characteristics of Polymeric Solids, Creep and Stress Relaxation, Heat Deflection Temperature, Selection of Matrix. Thermoplastics. Metal Matrix. Ceramic Matrix. Thermoset Matrix. Thermoplastic Matrix. Surface treatment for fibers. Fillers and Other Additives. Incorporation of Fibers into Matrix. Fiber Content, Density, and Void Content. Fiber Architecture.

**MODULE II**

Composite materials. Mechanics- Fiber–Matrix Interactions in a Unidirectional Lamina, Longitudinal Tensile Loading, Unidirectional Continuous Fibers, Unidirectional Discontinuous Fibers, Microfailure Modes in Longitudinal Tension, Transverse Tensile Loading, Longitudinal Compressive Loading, Transverse Compressive Loading. Characteristics of a Fiber-reinforced Lamina Fundamentals. Isotropic, Anisotropic, and Orthotropic Materials .Rule of Mixtures - invariant properties of orthotropic laminates – strength of an orthotropic lamina - failure criteria of orthoptropic lamina - macro mechanical behavior of laminates

Metal, Ceramic, and Carbon Matrix Composites- Metal Matrix Composites-Mechanical Properties, Continuous-Fiber MMC, Discontinuously Reinforced MMC, Manufacturing Processes, Continuously Reinforced MMC,Discontinuously Reinforced MMC. Ceramic Matrix Composites- Micromechanics, Mechanical Properties. Glass Matrix Composites. Polycrystalline Ceramic Matrix, Manufacturing Processes, Powder Consolidation Process, Chemical Processes. Carbon Matrix Composites.

**MODULE III**

Composite Manufacturing- Fundamentals, Degree of Cure, Viscosity, Resin Flow, Consolidation, Gel-Time Test, Shrinkage, Voids. Bag-Molding Process. Compression Molding. Pultrusion. Filament Winding, Liquid Composite Molding Processes, Structural Reaction Injection Molding. Other Manufacturing Processes - Resin Film Infusion, Elastic Reservoir Molding,, Tube Rolling Manufacturing Processes for Thermoplastic Matrix Composites.

Quality Inspection Methods for composite materials- Raw Materials, Cure Cycle Monitoring, Cured Composite Part, Radiography, Ultrasonic, Acoustic Emission, Acousto-Ultrasonic and Thermography methods.

**MODULE IV**

Polymers- Structure of polymers, Polymerisation, Molecular weight, Bonding, Linear and branched polymers, Crystallinity. Glass transition temperature. Thermoplastics-Effects of temperature and rate of deformation, Crazing, Thermosetting plastics, Thermal and electrical properties, Creep and stress relaxation. Electrically conducting polymers. Additives. Types, properties and applications of thermoplastics. Thermosetting plastics-Types and applications. Biodegradable plastics. Elastomers. Polymer processing- Mixing devices, Injection Moulding,Extrusion, Special moulding methods like matched mould forming ,air blowing, vacuum forming techniques, thermo forming, blow moulding,rotation moulding,plastic finishing techniques. Basics of polymer characterization methods.

Polymer Nanocomposites- Nanoclay .Carbon Nanofibers. Carbon Nanotubes- Structure, Production of Carbon Nanotubes, Mechanical Properties of Carbon Nanotubes, Carbon Nanotube–Polymer Composites, Properties of Carbon Nanotube–Polymer Composites.

**MODULE V**

Ceramics-Structure, Chemical bonding, Raw materials, Classifications, oxide and other ceramics, silica, nanophase ceramics and composites, Properties- mechanical, thermal, dielectric, magnetic and optical properties. Toughening mechanism. Processing of ceramics. Applications. Glasses, Mechanical properties, Glass ceramics-formation, structure and properties.Advanced ceramics- Definition, General Improvements in Mechanical Properties.Monolithic advanced ceramics-Aluminum Oxide, Silicon Nitride, Silicon Carbide, Transformation-toughened Zirconia, Self-Reinforced Ceramic Composites, Formation of a Precipitate or Dispersion of Crystals During Heat Treating, Particle-Reinforced Ceramic Composites, Whisker-Reinforced Ceramic Matrix Composites, Novel Ceramic Matrix Composite Fabrication Approaches, Reaction Formed with a Ductile Metal Reinforcement Phase, Fibrous Monolith Composites.Bioceramics.

**Text books**

1. Composite Materials- K. K. Chawla ,Science & Engineering, Springer, 2008.
2. Polymer Science- V.R. Gowarikar, N.V.Viswanathan and JayadevSreedhar, Wiley Eastern Limited, Madras ,2006
3. Introduction to Polymers- R.J. Young, Chapman and Hall Ltd., London, 1999.
4. Text Book Of Polymer Science- Billmeyer, John Wiley & Sons(Asia) Pvt Ltd,1994
5. Ceramic Technology and Processing- Alan King, Standard Publishers Distributors, 2004.
6. Introduction to the Principles of Ceramic Processing- James S. Reed, John Wiley, 1995.
7. Fundamentals of ceramics- Michel W Barsoum, IOP Publishing,Bristol, 2003.
8. Hand book of Advanced Materials- EdJames K. Wessel,WileyInterscience, 2004.
9. Manufacturing Engineering and Technology-S.Kalpakjian, R.Schmid, Pearson, 2012.

**Reference books**

1. Composite Materials, Vol 1 & 2, Mel. M. Schwartz Prentice - Hall PTR, New Jersey, 1997.
2. ASM Hand Book – Composites, V 21- ASM International, Ohio, 2001.
3. Fundamentals of composite Manufacturings- Materials ,Methods and Applications, - A.B.Strong, SME 1989.
4. Polymer Chemistry - An Introduction, 2nd Edition, B. Raymond, Seymour and Charles E. CarraherJr:MarcelDekkar, Inc. New York, 1987.
5. Ceramic Material, Science and Engineering- C.B.Carter, M.G.Norton,Springer, 2007.

**MODEL QUESTION PAPER**

**MT 010 703 CERAMICS, POLYMERS AND COMPOSITES MATERIALS**

**PART A (5 X 3 =15 marks)**

1. Define fiber architecture. What are its characteristics?
2. What is understood by compocasting?
3. Briefly explain Pultrusion.
4. Explain “Crazing” in thermoplastics.
5. What are glasses?

**PART B (5 X 5 =25 marks)**

1. Give a comparison of the strength of various fibers used to make composite materials.
2. Give a brief account of Carbon matrix composites.
3. How will you monitor the curing cycle of a composite material?
4. Explain biodegradability of plastics.
5. What are “bio ceramics”?

**PART C (5 X 12 =60 marks)**

1. Explain the methods to incorporate fibers into the matrix to prepare a composite material.

**OR**

1. Kevlar 49 fiber strands are used in many high strength cable applications where its outstanding strength–weight ratio leads to a considerable weight saving over steel cables. (a) Com pare the breaking loads and weights of Kevlar 49 and steel cables, each with a 6.4 mm diameter, (b) Compare the maxi mum stresses and elongations in 1000 m long Kevlar 49 and steel cables due to their own weights.
2. A unidirectional fiber composite contains 60 vol% of HMS-4 carbon fibers in an epoxy matrix. The fiber properties-density 1.8 g/cc, Tensile modulus-345 GPa, Tensile strength 2.48 GPa, strain to failure 0.7%. Matrix properties - Em = 3.45 GPaand σmy = 138 MPa, determine the longitudinal tensile strength of the composite for the following cases: (a) The fibers are all continuous. (b) The fibers are 3.17 mm long and πi is (i) 4.11 MPa or (ii) 41.1 MPa.

**OR**

1. Do metal matrix composites have advantages over reinforced plastics? Explain.
2. Briefly explain the liquid composite moulding processes.

**OR**

1. What are the non destructive methods to inspect a component made of a composite material? Explain one of them with neat sketches.
2. a)Why is there so much variation in the stiffness of polymers?b) How can you make polymers to conduct electricity?c) Discuss the significance of glass transition temperature in engineering applications.

**OR**

1. a) Give a brief account of Carbon nano tubes- their structure, production and properties.b) Explain the methods to prepare CNT-Polymer composites.
2. a) A fully ceramic has these properties- UTS0 – 180 MPa. E0 -300 GPa. What will be the values of these properties at 20% porosity for n= 4,5,6&7 respectively.b) Explain why ceramics are not used as fasteners.

**OR**

1. a)Calculate the thermal conductivities for ceramics at porosities of 10%,20% and 30% for k 0= 0.7W/m.K .b)How are ceramics made tougher?

**MT 010 704 THEORY OF METAL FORMING**

**Teaching Scheme Credits 4**

3 hours lecture and 1 hour tutorial per week.

**Objectives**

This course is designed to give the students of metallurgy insight to the principles and techniques to convert a solidified ingot of a metallic material to usable forms.

**MODULE I**

Introduction to various manufacturing processes.

Fundamentals of Metalworking- Classification of Forming Processes. Mechanics ofMetalworking.Plasticity, Flow-Stress Determination. Work hardening.Softening mechanisms,Temperature in Metalworking .Strain-Rate Effects. Metallurgical Structure . Friction and Lubrication. Deformation-Zone Geometry. Hydrostatic Pressure. Workability. Experimental Techniques for Metalworking Processes . Workability and process design.Bulk workability of metals. Evolution of microstructure during hot working.Workability tests.Alternative deformation mechanisms-creep, grain boundary sliding,twinning.

**MODULE II**

Forging - Classification of Forging Processes. Forging Equipments- Hammers and Presses. Selection of forging equipment, Dies and die materials for hot forging, lubrication, Forgeability tests, Forging die design, Forging in Plane Strain. Importance of flow lines in forging.Open-Die Forging- Upsetting, Barreling, Cogging, Calculation of forging force. Impression die and Closed-Die Forging . Flash formation. Fullering, Edging, Blocking, Flashless forging, Calculation of Forging Loads in Closed-Die Forging . Basics of various forging operations-Hot upset forging. Roll forging, Skew rolling, Orbital forging, Incremental forging, Rotary swaging,High energy rate forging, Isothermal and hot die forging, Rotary forging, Coining. Salient features of forging of Carbon and alloy steels, stainless steels, heat resistant alloys and non ferrous alloys( Al, Cu, Ni, Mg, Ti) Forging Defects. Powder (Metallurgy) Forging. Residual Stresses in Forgings.Piercing,Mandrel forging and ring rolling.Severe plastic deformation by ECAP – types, microstructural variation with different processing routes, multichannel ECA.

**MODULE III**

Rolling of Metals-Classification of Rolling Processes . Hot-Rolling. Cold-Rollingills..Types of rolling m Rolling of Bars andShapes. Forces and Geometrical Relationships in Rolling . Simplified Analysis of Rolling Load: Rolling Variables .Mechanics of rolling. Roll force and power requirement ,Front and back tension, Camber, flattening , spreading during rolling, Flat rolling practice , Problems and Defects in Rolled Products. Rolling-MillControl . Theories of Cold-Rolling . Theories ofHot-Rolling . Torque and Power. Thread rolling. Production of seamless pipes and tubes-Pilgering.

**MODULE IV**

Extrusion of Metals- Classification of Extrusion Processes . ExtrusionEquipment . Hot Extrusion .forces in hot extrusion.Deformation, Lubricationand Defects in Extrusion. Die design and die materials. Analysis of the Extrusion Process. Cold Extrusion and Cold-Forming .Impact extrusion. Hydrostatic Extrusion .Extrusion of Tubing. Production of Seamless Pipe andTubing.

Drawing of Rods, Wires, and Tubes – Introduction. Rod and Wiredrawing. Analysisof Wiredrawing. Die design, die materials, lubrication. Tube-Drawing Processes . Analysisof Tube Drawing .Defects and Residual Stresses in Rod, Wire, and Tubes

**MODULE V**

Sheet-Metal Forming- Introduction ,Characteristics of sheet metal forming processes, Forming Methods, Shearing andBlanking, Punch force in shearing, Dies for shearing. Shearing metal characteristics. Formability tests for sheet metals- cupping test, forming limit diagrams.

Other sheet metal forming operations-Spinning, Rubber pad forming, Three rolls and counter roll forming, Explosive and electromagnetic forming.Bending, Spring back effect, Bending force, bending operations, Tube bending. Stretch Forming. DeepDrawing, Deep drawability.Shearing of plates and sheets. Laser, thermal and water-jet cutting.Superplastic forming. Rapid Prototype Operations.

Texture development and residual stresses in Thermo-mechanical processing. Comparison of mechanical forming operations with casting.

**Text books**

1. Mechanical metallurgy , SI Metric Edition, George E. Dieter, McGraw-Hill, London,1988.
2. Powder Handbook of Workability and Process Design, Ed George Ellwood Dieter, ASM International,2003.
3. Thermo mechanical processing of Metallic Materials, Bert Verlindenetal, Elsevier, NewYork 2007.
4. Metal forming mechanics and metallurgy -Hosford W.F. and Caddell R.M, PrinticeHall 1983.

**Reference books**

1. ASM Hand Book Vol 14-Forming and forging, ASM International, ASM, Ohio, 1993.
2. Hot Working Guide: A Compendium of Processing Maps, YVRK Prasad, Sasidhara, ASM International.

**MODEL QUESTION PAPER**

**MT 010 704 THEORY OF METAL FORMING**

**PART A (5 X 3 =15 marks)**

1. What is understood by “workability” of a material?
2. Name the various defects that can appear in a steel forging.
3. Explain the effect of applicationof longitudinal tensions during strip rolling.
4. Bring out the differences between extrusion and drawing.
5. Explain the differences between compound, progressive and transfer dies.

**PART B (5 X 5 =25 marks)**

1. With the help of a processing map, explain the “Safe Working region” for an alloy.
2. Explain with relevant sketches the basics of closed and open die forging?
3. Explain the effects of wall-to-thickness ratio of the feed material, friction and ratio of roll radius to strip thickness on the spreading in flat rolling.
4. How do the extrusion ratio, speed and temperature affect the extrusion force?
5. Explain Superplastic forming of metals and alloys.

**PART C (5 X 12 =60 marks)**

1. Explain, Hot working, cold working and warm working of metals with examples.

**OR**

1. In a ring compression test a specimen 10 mm high with outside diameter 60 mm and inside diameter 30 mm is reduced in height by 50 percent. Determine the friction factor if (a) the OD after deformation is 70 mm and (b) the OD after deformation is 81.4 mm. Determine the peak pressure at the center of a 60-mm-diameter cylinder compressed 50 percent for each case.
2. Name the three major classes of Ti alloys. What are their characteristics? Explain the effects of forging temperature, deformation rate and die temperature on the forgeability of Ti alloys.

**OR**

1. Bring out the differences between the mandrel forging and ring rolling operations in the forming of a steel ring. What are their advantages and limitations?
2. Explain the processes to manufacture seamless tubes.

**OR**

1. What are the different types of rolling defects? Explain with neat sketches. Suggest measures to be taken to avoid or reduce them.
2. a) Show that for a perfectly plastic material, under frictionless condition, pressure “p” in direct extrusion is



b) Show that for the same conditions,



A0- Initial area. Af- final area.Y= yield stress.. σd – wire drawing stress.

**OR**

1. Calculate the force required to extrude copper at 700C . The billet dia is 125 mm and extrusion ratio is 20.What is the final temperature of the billet?Assumption- No heat is lost through the tooling.
2. Describe the hydroforming process. The drawability of a material is higher in this operation is higher than in the deep drawing process. Why?

**OR**

1. Explain the effect of friction on a Forming limit diagram. Describe the Cupping test for sheet metals.

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**MT 010 705 POWDER METALLURGY**

**Teaching Scheme Credits 4**

3 hours lecture and 1 hour tutorial per week.

**Objectives**

To provide the student with knowledgeabout fabrication of components using powder metallurgical methods. The course gives a detailed insight of the materials,their fabrication processes, quality assessment and control and modern developments.

**MODULE I**

Introduction- History of powder metallurgy, basics, applications, advantages and limitations. Introduction to metal powder production and characterization. Criteria for the selection of powder production method.

Powder production- Chemical Methods- Chemical Reduction from solid, gaseous and aqueous states, Precipitation from solution,Chemical (thermal) Decomposition of compounds (hydrides and carbonyls). Physical Methods -Electrolytic Methods - direct process, brittle cathode process. Atomization-characteristics of atomized powders, gas, water, liquid gas, centrifugal, rotating electrode, vacuum and ultrasonic atomization methods and their mechanisms. Granulation and drying. Mechanical Methods – milling of brittle and ductile materials - principle and processes- impact, attrition , shear and compression methods to make powders. Mechanical alloying-principle, processes, Applications-ODS alloys,Ni and Fe base alloys,Al and Mg base alloys, synthesis of non equilibrium phases, powder contamination, industrial applications.

**MODULE II**

Production of powders of iron, steel, Cu , Al ,Ti, Co, Be and their alloys, precious metals. Ultrafine and nano structures powders and their production methods.Powder characterization - chemical composition, structure, particle size and shape, surface area,particle surface topography, apparent and tap density, flow rate, compressibility, green strength, pyrophorocity and toxicity, density, segregation tendency.Powder classification methods-counterflow equilibrium and cross flow separation, sieving. Sedimentation methods of classification.Powder Treatment – Powder annealing, mixing, particle size reduction,coating.

**MODULE III**

Powder consolidation. Compaction-Introduction, die compaction, die filling and pressing operations, single and double action compaction, split die systems, tooling design, tool materials, rotary presses, press requirements, press selection- mechanical and hydraulic, factors affecting tooling design, apparent density, flow, fill ratio, compaction pressure, dimensional changes, part classification, parameters of part geometry.CIP- instrumentation, operation and applications, defects due to tooling limitations. Dynamic powder compaction. Sintering –Introduction, consolidation principle. Types of sintering- Liquid Phase and Activated Sintering,Loose Sintering.Sintering process variables, Material Variables, Dimensional Changes,Microstructural Changes, Sintering Atmosphere – Hydrogen, Reformed Hydrocarbon Gases, Nitrogen and its based Atmospheres, Dissociated Ammonia, Argon and Helium, Vacuum. Sintering Atmosphere Analysis and Control - Gas Analysis, Specific Gravity Analysis, Moisture Determination, Carbon Potential Control. Sintering Furnaces-Batch Type Furnaces, Continuous Sintering Furnace, Vacuum Furnaces , Electric Furnace Heating Elements. Sintering Zones. Consolidation of nanocrystalline and ultrafine powders.

**MODULE IV**

Secondary treatment - machining , impregnation , surface engineering, steam treatment , coating. Heat treatment –effect of porosity on material properties, hardenability of ferrous P/M parts, influence of alloy content on hardenability, case hardening-carburising ,carbonitriding, nitrocarburising.Influence of porosity on case depth. Tempering, age hardening, , sinter hardening. Joining of powder metallurgy parts- methods. Techniques to improve dimensional tolerance. Machinability of PM parts.

Other high temperature compacting processes- Principle, process, applications of metal injection moulding, powder rolling, powder extrusion, pressureless compaction, spray deposition, spark sintering.

High density compaction – Hipping.

**MODULE V**

Resin impregnation of powder metallurgy parts- need and benefits.Testing and Quality Control of PM Materials and Products – dimensional evaluation, sampling , density , mechanical Properties , fracture , roughness , electrical resistivity , magnetic properties , metallography , corrosion resistance. Case studies of quality control.Powder metallurgy and applications of steels, Al, Cu, Ti, Be, refractory alloys. Powder metallurgy of gears, bearings, foams. Techno-economics of PM Processing, Powder metallurgy of ceramics- types, powder preparation and processing of PM parts, properties and applications -cermets, cemented carbides. Specialty applications of metal powders. Metallic and Ceramic PM materials .

High strain rate processing of powder metallurgy parts.

**Text books**

1. Powder metallurgy technology, G.S.Upadhyaya, Cambridge international publishing, UK, 2002.
2. Powder metallurgy science, technology and materials, Anish Upadhyaya, G S Upadhyaya, Universities Press, Hyderabad.
3. Introduction to powder metallurgy, American powder metallurgy Institute, 1976.
4. Powder metallurgy, science, technology and applications, P C Angelo, R Subramanian, PHI, N.Delhi, 2006.

**Reference books**

1. Non-equilibrium Processing of Materials, Ed. C.Suryanarayana, Pergamon, 1999.
2. Hand book of powder metallurgy, H.H.Hausner, M.Kumar Mal, Chemical publishing company, New York, 1998.
3. Sintering, grain growth and microstructure, Suk-Joong L Kang, Elsevier, 2005.
4. ASM Metal Hand book Vol 7,ASM International, Ohio, 1998.
5. Modern developmentsInPowder metallurgy, Editor -Henry H. Hausner ,Plenum press, New York, 1966.
6. Hot Working Guide: A Compendium of Processing Maps, Ed Y. V. R. K. Prasad, S. Sasidhara, ASM International, 1997.

**MODEL QUESTION PAPER**

**MT 010 705 POWDER METALLURGY**

**PART A (5 X 3 =15 marks)**

1. What are the advantages of powder metallurgy over other manufacturing processes? What are the criteria for selecting the powder production method?
2. Describe the term “green” in powder metallurgy. Why is green strength important?
3. Name the factors affecting tooling design in powder compaction.
4. Explain the effect of density and tempering on impact energy of a powder metallurgy part.
5. What are the causes of dimensional changes in a powder metallurgy component?

**PART B (5 X 5 =25 marks)**

1. Explain briefly the atomization method to produce metal powders.
2. What is understood by the terms “apparent and tap density” in powder metallurgy?
3. Describe what happens during sintering of a green compact.
4. Explain briefly steam treating of powder metallurgy parts.
5. What is understood by resin impregnation of powder metallurgy parts? What are its advantages?

**PART C (5 X 12 =60 marks)**

1. Explain with neat sketches the electrolytic methods of metallic powder production.

**OR**

1. Give a brief note on ODS alloys. Explain the mechanical alloying process.
2. Explain the methods commonly used to coat metal powders prior to compaction.

**OR**

1. With the help of suitable sketches, explain the methods to produce Aluminium powders commercially.
2. Explain with neat sketches cold isostatic pressing. What are its advantages and applications?

**OR**

1. What is Liquid phase sintering? Explain its theory, process and applications.
2. Explain powder injection molding technique with necessary figures.

**OR**

1. What are the factors affecting the machinability of steel powder metallurgy products? What are the measures to be adopted to improve the machinability?
2. What are cermets? What are its applications? Briefly explain the necessary steps to make a cermet component using powder metallurgy route.

**OR**

1. Briefly explain the theory and practice of high strain rate processing of powder metallurgy components.

**MT 010 706 L01 EMERGING MATERIALS**

**Teaching Scheme Credits 3**

2 hours lecture and 1 hour tutorial per week.

**Objectives**

To introduce to the students of metallurgy and materials science information on new, exotic materials for higt-ech applications, emphasizing the physics, properties, fabrication.

**MODULE I**

Types and characteristics of Smart materials-Fundamental characteristics. Solid materials- Introduction of advanced materials and its manufacturing processes for engineering applications- smart materials- Classification of smart materials. Basics of property changing smart materials-Photcromics, thermocromics, mechanochomics, electrochromics.Phase changing materials, Conducting polymers and other conductors, Rheological property changing materials, Liquid crystal technologies, Suspended particle displays. Energy exchanging smart materials -Light emitting materials,

Functionally graded materials- Classification, Characteristics, Behavior and Performance, Mechanical Behavior, Plastic Deformation and Fracture, Thermomechanical Behavior, Electrical and Optical Characteristics. Applications- environmental protection systems, wear resistant coatings, joining, energy conversion,optical fibers, fuel cells. Fabrication of FGMs.

**MODULE II**

Hydrogen storage materials- Storage of Hydrogen in pure form-Joule Thompson coefficient, Gaseous storage. Liquid storage. Hybrid and super critical storage, Hydrogen slush.Physisorption in Porous Materials-Carbon Materials, Organic Polymers, Zeolites, Coordination Polymers. Metal Hydrides-Elemental Hydrides, Ionic or Saline Hydrides, Covalent Hydrides, Metallic Hydrides, Intermetallic Compounds, Crystal Structure , Synthesis, activation, Hysteresis ,Hydrogenation Kinetics , Cycle Life. Decrepitation. Other Hydrogen storage materials.

**MODULE II**

Thermo Electric Materials (TEM)-Concept of phonon.Thermal conductivity. Specific heat.Exothermic -endothermic processes. Different types of TEM -Bulk TEM Properties,Onedimensional TEM. Composite TEM-Applications.

Piezoelectric materials (PZT): piezoelectric effect, Di-electric hysteresis, piezoelectric constants,piezoelectric charge constants, dynamic behaviour of PZT transducers, piezoelectric materialsand manufacturing techniques (stability, poling and depolarisation).

Electro rheological(ER) and magneto-rheological (MR) materials: Characteristics of ER and EM fluids. ER materials.

**MODULE IV**

Importance of Nano-technology, History of Nano-Technology, Properties of Nano materials,Difference between bulk and nanomaterial. Molecular building blocks for nanostructuresystems. Influence of Nano structure on mechanical, optical, electronic, magnetic and chemicalproperties. Carbon Nano Structures-Introduction- Fullerenes . Types of Nano-tubes- assemblies- synthesisof carbon nanotubes -C60, C80 and C240 Nanostructures- carbon nanotube interconnects. Mechanical,optical and electrical properties of carbon nano-tubes.Applications of carbon nano-tubes. Graphine. Synthesis of bulk nano-structured materials – Lithographic techniques. Etching techniques, Wet chemical etching , Dry etching.Ball milling technique- mechanical alloying.Sol-gel synthesis . Spin coating. Thin film techniques - Molecular beam epitaxy, Liquid phaseepitaxy, Sputtering technologies- Ion deposition, Ion implantation. Electrodeposition- Cathodic arc deposition, Pulsed laser deposition, Chemical Vapor Deposition, CVD, Plasma CVD- Photo-enhanced CVD /PVD. Atomic Layer Deposition. Equi Channel Processing of metallic materials.

**MODULE V**

High temperature materials-Characteristics of high-temperature materials ,Thesuperalloys as high-temperature materials, applications, Historical development of the superalloys , Nickel as a high-temperature material: justification.Composition–microstructure relationships in nickel alloys , The FCC phase, phases in the superalloys. Defects in nickel and its alloys- Defects in the gamma (FCC), gamma prime phases. Strengthening effects in nickel alloys. The creep behaviour of nickel alloys.Single-crystal superalloys for blade applications**-** Processing of turbine blade by solidification processing.Processing of the turbine disc alloys -processing by the cast and wrought route, processing by the powder route.Coatings - Processes for the deposition of coatings on the superalloys, Thermal barrier coatings, Overlay coatings , Diffusion coatings. Future trends.Iron and Cobalt base alloys.

**TEXT BOOKS :**

1. Smart Materials and New Technologies- D. Michelle Addington Daniel L. Schodek, Elsevier, 2005.
2. Handbook of advanced materials enabling new designs , Ed.James K. Wessel, Wiley Eastern , 2004.
3. Handbook of Hydrogen Storage: New Materials for Future Energy Storage-Ed.MichaelHirscher,Wiley VCH ,2010.
4. Nano: The Essentials - T.Pradeep - Tata McGraw Hill, New Delhi, 2007 .
5. Introduction to Nanotechnology- Charles P.Poole, Jr. and Frank J.Owens ,Wiley, 2003 .
6. Piezoelectricity -W.Taylor George Gorden and Breach Sc. Pub., 1985
7. Smart materials and Structures- M.V. Gandhi, B.S Thompson, Chapman and Hall, 1992.
8. The Superalloys -Fundamentals and Applications-Roger C. Reed, Cambridge university press

Cambridge, 2006.

**REFERENCE BOOKS:**

1. Introduction to Nanoscience and NanoTechnology,-Chris Binns, John Wiley and Sons.,2010.
2. Basics of Nano Technology- Horst-Gunter Rubahn, Wiley-VCH Verlag Gmbh,2008.
3. Nano structures and Nano materials: Synthesis, properties andapplications - Guozhong Cao, Imperial College press.
4. Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1998.
5. Handbook of NanoScience, engineering and technology- SV. Gaponenko, CRC Press, 2007.
6. Carbon Nanotubes: Properties and Applications-Michael J. O’Connell, CRC/Taylor& Francis, 2006.
7. Handbook of Thermo-electrics- CR Rowe, CRC Press, 1995 .
8. Handbook of NanoScience, engineering and technology,-W.Goddard CRC Press, 2007.

**MODEL QUESTION PAPER**

**MT 010 706 L01 EMERGING MATERIALS**

**PART A (5 X 3 =15 marks)**

1. Name the four types of “colour changing” materials. Give examples.
2. What is “Joule-Thompson Coefficient”?
3. What are thermoelectric materials? What are their applications?
4. Why do the properties of nanostructured materials differ from bulk materials?
5. What do you understand by the term “superalloys”? What are the commonly used superalloy types used by industries?

**PART B (5 X 5 =25 marks)**

1. What is electroluminescence? Give the applications of materials showing this property.
2. Explain the need to store Hydrogen.
3. Explain the piezo electric effect. How can you use this phenomenon in the non destructive testing of materials.
4. Whatis a buckyball? Give thedifferences in the structures of a bucky ball and graphite.
5. “Nickel is a high temperature material”. Justify.

**PART C (5 X 12 =60 marks)**

1. Explain the types and characteristics of smart materials.

**OR**

12. What are “FGMs”? Where are they used. Give a brief account of the techniques used to fabricate FGMs.

13. Explain the physisorption of Hydrogen in porous materials. Give examples.

**OR**

14.How will you store pure hydrogen? Explain its thermodynamic principles.

15.Explain the principle and design of a portable refrigerator you are asked to make.

**OR**

16.What are rheological materials? Give their classification and applications.

17.Explain the method to obtain nanostructure in bulk metallic materials.

**OR**

18. Give a detailed account of Carbon nano tubes with respect to their types, properties, synthesis and applications.

19.Explain the hardening mechanisms in Nickel base superalloys.

**OR**

1. How will you prepare a single crystal blade for a turbo engine? Why is it technologically superior to a blade formed by other manufacturing methods?

**MT 010 706 L02 HIGH TEMPERATURE MATERIALS**

**Teaching Scheme Credits 4**

3 hours lecture and 1 hour tutorial per week.

**Objectives**

To have an understanding of the materials used for elevated temperature applications.

**MODULE I**

Factors influencing functional life of components at elevated temperature, definition of creep curve, various stages of creep, metallurgical factors influencing various stages, effect of stress, temperature and strain rate.Design of transient creep, time hardening, strain hardening, expressions for rupture life for creep, ductile and brittle materials, Monkman - Grant relationship

**MODULE II**

Ferrous heat resistant alloys and their properties- Elevated temperature mechanical properties of Carbon and alloy steels, Chromium steels, Cr-Mo-V steels, hot work tool and die steel, maraging steels, short and long term elevated temperature tests, tempered martensite embrittlement, creep embrittlement, creep fatigue interaction. Stainless steels and their high temperature properties, thermally induced embrittlement.

**MODULE III**

Properties of non- ferrous heat resistant materials- Titanium and its alloys, coatings. Refractory metals and alloys- Molybdenum, tungsten, Niobium, Tantalum, Rhenium alloys, their elevated temperature properties and applications. Nickel-chromium and Nickel- Thoria alloys, Structural intermetallics. Structural ceramics- types, applications, properties, processing. Carbon - Carbon composites-architecture, processing, properties, coatings.

**MODULE IV**

Making and shaping of super alloys for high temperature applications- Melting and conversion- solidification of super alloys, EAF, VIM, VAR, ESR. Ingot conversion and mill products. Investment castings. Forging and forming. Powder metallurgy of super alloys. Heat treating. Joining techniques. Single crystals and turbine blades. Trade names and uses of most common super alloys.

**MODULE V**

Oxidation and hot corrosion -Oxidation, Pilling Bedworth ratio, kinetic laws of oxidation – defect structure and control of oxidation by alloy additions, corrosion deposit, fluxing mechanisms, effect of alloying elements on hot corrosion, interaction of hot corrosion and creep, methods of combat hot corrosion. High temperature corrosion of carbon steels, alloy steels , stainless steels and super alloys. Protection coatings. Metal dusting corrosion of metals and alloys- Introduction and background, nature of the metal dusting environment, metal dusting of pure metals, metal dusting of alloys, control of metal dusting.

**TEXT BOOKS .**

1. Heat Resistant Materials- ASM Speciality Hand book- ASM International, Ohio.
2. Deformation and Fracture Mechanics of Engineering materials- Hertzberg R.W., 4th  
   Edition, John Wiley, USA, 1996.
3. Mechanical Behaviour of Materials- Courtney T .H McGraw-Hill, USA, 1990.
4. Superalloys- A technical guide-Mathew J. Donachie, Stephen J. Donachie, ASM International, Ohio, 2002.

**REFERENCES.**

1. Directionally Solidified Materials for High Temperature Service, McLean D,The Metals Society, USA, 1985.

**MODEL QUESTION PAPER**

**MT 010 706 L02 HIGH TEMPERATURE MATERIALS**

**PART A (5 X 3 =15 marks)**

1. Define super plasticity.
2. What are refractory metals?
3. Explain the term “super alloys”. Give examples with nominal compositions.
4. What is investment casting and how is it applied to super alloys?
5. Explain “pilling”.

**PART B (5 X 5 =25 marks)**

1. Draw and explain a typical creep curve and mark the various stages.
2. What are TCP phase of super alloys?
3. Explain the protective atmospheres normally employed during the heat treatment of superalloys?
4. What is the difference between n-type and p-type oxides?
5. Derive the expression for the rupture life of a component subjected to creep.

**PART C (5 X 12 =60 marks)**

1. Explain in detail about the factors influencing functional life of components at elevated temperatures.

**OR**

1. Write technical notes on various creep mechanisms.
2. Derive expression for Creep ductile and creep brittle fractures .Also comment on theinstantaneous fractures in both cases.

**OR**

1. (i) How will you obtain creep resistance through strain hardening?

(ii)Explain stress rupture test at elevated temperature.

1. Derive an expression for cleavage I failure based on Orowan and Griffith Theory andcomment how the various terms in these equations are responsible for strengthening andtoughening the materials.

**OR**

1. Analyse technically the following fractures

(i) Trans Granular Ductile fracture.

(ii) Inter granular creep fracture.

(iii) Pure diffusional Fracture.

(iv) Rupture.

1. What are the kinematics principles in the Oxidation? Discuss in detail.

**OR**

1. Fluxing in hot corrosion in loss of protective oxide due to dissolution. Analyze thevarious models for basic and acidic fluxing and effect of electrochemical polarization onfluxing of various oxides with the help of phase stability diagrams
2. Explain strengthening of cobalt-base super alloys.

**OR**

1. Draw fracture maps for pure Ni chrome a solid solution and a precipitation hardenednickel base super alloy and explain how the boundaries shifts due to alloying andprecipitation.

**MT 010 706 L03 SEMICONDUCTING MATERIALS AND DEVICES**

**Teaching Schemes Credits:** 3

2 hours lecture and 1 hour tutorial per week.

**Objectives:**

To make the students to understand the physical, electrical, and optical properties of semiconductor materials and their use in microelectronic circuits and to relate the atomic and physical properties of semiconductor materials to device and circuit performance issues

**MODULE I**

Review of Atomic Structure and Statistical Mechanics:- Atomic structure, Wave particle duality, Quantum mechanics, The Schrodinger wave equation, Electronic structure of atoms & Periodic table of elements, Statistical mechanics. Crystalline Solids and Energy Bands:- Atomic bonds, Crystal structures, Crystal defects, Lattice vibration and phonons, Energy bands in solids, Metals and insulators.

**MODULE II**

Semiconductor Materials and Their Properties:- Semiconducting materials, Elkemental and compound semiconductors, Valence bond model of the semiconductor, Energy band model, Equlibrium concentrations of electrons and holes inside energy bands, Fermi level and energy distribution carriers inside the band, Temperature dependence of carrier concentration, Heavily doped semiconductors. Carrier Transport in Semiconductors:- The drift of carrier in an electric field, Variation of mobility with temperature and doping level, Conductivity, Impurity band conduction, The Hall Effect, Non linear conductivity, Carrier flow by diffusion, Einstein relations, Constancy of the Fermi level across a junction. Excess Carriers in Semiconductors:- Injuction of excess carriers, recombination of excess carriers, Mechanism of recombination processes, Origin of recombination centers, Excess carriers and quasi-Fermi levels, Basic equations of semiconductor device operations.

**MODULE III**

Junctions and Interfaces: p-n junction:- Description of p-n junction, The abrupt junction, Linearly graded junction, The diffused junction. Characteristics of a p-n junction- The ideal diode model, Real diodes, Temerature dependence of I-V characteristics, High level injection effects, Exaples of p-n junction diodes. Electrical Breakdown in p-n Junctions:-Description of breakdown mechanisms, Zener breakdown in p-n junctions, Avalanche breakdown in p-n junction, Effect of junction curvature and crystal imperfections on breakdown voltage, Application of breakdown diodes. Dynamic Behaviour of p-n Junction Diodes:-Small signal ac impedance of a junction diode, Charge control equation and switching transients in a junction diode, High speed switching diode.Tunnel Diode, Backward diode, Schottky barrier diode, Ohmic contacts, Hetrojunctions.

**MODULE IV**

Semiconductor Devices: Microwave Diodes:- The Varactor diode, p-i-n diode, IMPATT diode, TRAPATT diode, BARITT diode, Transferred electron device. Optoelectronic Devices:- Solar cell, Photodetectors, Light emitting diodes, Semiconductor lasers. Bipolar Junction Transisters:- Principle of operation, Fabrication and dopping profiles Analysis of the ideal diffusion transistor, Real transistors, Static I-V characteristics in the normal actgive region, Charge control equations, Diffusion transistor at high frequencies, The drift transistor, Power transistors, The switching transistors. Metal-Semiconductor Field Effect Transistors (MESFET):- Principle of operation, I-V characteristics of idealized model, Basic types of MESFETs, Short channel MESFETS, High frequency performance, MOSFET structures. MOS Transistors and Charge Couple Devices:- Semiconductor surface, C-V characteristics of MOS capacitor, Basic structure and operating principle of MOSFET, I-V characteristics, Transister rating and frequency limitations, Charge-coupled devices. Power Rectifiers and Thyristors:- Power rectifiers, Thyristors, Special thyristor structures, Bidirectional thyristor, Field controlled thyristor.

**MODULE V**

Technology of Semiconductor Devices and integrated Circuits:- Crystal growth and wafer preparation, Methods of p-n junction formation, Growth and deposition of dielectric layers, The planar technology, Masking and Lithography, Pattern definition, Metal deposition technique, Integrated devices, Bipolar integration, MOS integration. Semiconductor Measurements:- Conductivity type, Resistivity, Hall effect measurements, Drift mobility, Minority carrier lifetime, Diffusion length.

**Books.**

1. Tyagi. M.S. Introduction to Semiconductor materials and Devices, John Wiley & Sons

**MODEL QUESTION PAPER**

**MT 010 706 L03 SEMICONDUCTING MATERIALS AND DEVICES**

**PART A(5 X 3 = 15 marks)**

1. What is de Broglie wave length?
2. Describe Hall effect.
3. What are the applications of breakdown diodes?
4. Give the parameter values and specifications of a JFET.
5. What is neutron transmutation doping?

**PART B(5 X 5 =25 marks)**

1. Write a short note on Phonons.
2. Explain why the carrier mobility in group II-IV semiconductors is lower than that in the group III-V and IV semiconductors.
3. What is an ideal diode? Describe the I-V characteristics of an ideal diode.
4. Compare enhancement MOSFET and depletion MOSFET.
5. Explain the crystal growth and wafer preparation methods.

**PART C(5 X 12 = 60 marks)**

1. Define the packing efficiency of a lattice. Show that packing efficiency is 34, 52 and 74 percentages for diamond lattice, simple cubic and, face centered cubic lattice respectively.

**OR**

1. Describe the electronic structure of atoms and the periodic table of elements.
2. Explain the energy band representation of intrinsic and extrinsic semiconductors.

**OR**

1. Describe the various scattering mechanisms in a semiconductor.
2. What is a real Diode? Explain the I-V characteristics of real diodes

**OR**

1. How does the crystal imperfections affect the breakdown voltage of a p-n junction
2. a) Explain the operation of a full wave rectifier (FWR) with centre tapped transformer & sketch the wave forms of input and output voltages. (b) Derive expressions for ripple factor, efficiency and % regulation in a FWR with resistive load

**OR**

1. (a) Draw the Eber-Moll circuit model for a PNP and NPN transistor. (b) Write a short note on switching transistor.
2. Explain the laboratory techniques for the conductivity and resistivity measurements of a semiconductor.

**OR**

20 Briefly discuss the methods of preparing various circuit components in an integrated circuit.

**MT 010 706 L04 ENGINEERING OPTIMIZATION TECHNIQUES**

**Teaching Schemes Credits:** 3

2 hours lecture and 1 hour tutorial per week.

**Objectives:**

Understand the need and origin of the optimization methods. Get a broad picture of the various applications of optimization methods used in engineering. Define an optimization problem and its various components.

**MODULE I**

Introduction to Optimization:- Requirement for the Application of Optimization Methods, Application of Optimization in Engineering:- Applications in design, Operation & planning, Analysis & data reduction, Classical mechanics, Taguchi system of quality engineering. Function of Single Variable:- Properties of single variable function, Optimality criteria, Region elimination methods, Polynomial approximation, Method s requiring derivatives- Newton-Raphson method, Bisection method, Secant method, Cubic search method. Problems. Function of Several Variables:- Optimality criteria, Direct search methods, Gradient based methods, Problems.

**MODULE II**

Linear Programming:- Linear programming methods,Graphical solution of linear programs in two variables, Linear programming in standard foarm, Principles of simplex method, Computer solution of linear programs, Sensitivity analysis in linear programming, Problems. Constrained Optimality Criteria:- Equality-constrained problems, Lagrange multipliers, Economic interpretation of Lagrange multipliers, Kuhn-Tucker conditions, Kuhn-Tucker theorems, Saddle point conditions, Second order optimality conditions, Generalised Lagrange multiplier method, Generalization of convex functions.

**MODULE III**

Transformation Methods:- Penalty concept, Algorithms, codes and other contributions, Method of multipliers- Penalty function, Multiploier update rule, Penalty function topology, Termination of the method, MOM characteristics, Choice of R-problem scale, variable bounds, Other MOM-type codes.

Constrained Direct Search:- Problem preparation, Adaptations of unconstrained search methods, Random search methods, Linearization Methods for Constrained Problems:- Direct use of successive linear programs, Separable programing

**MODULE IV**

Direction Generation Methods Based on Linearization:- Method of flexible directions, Simplex extensions for linearly constrained problems- Conves simples method, Reduced gradient method, Convergence acceleration, Generalised reduced gradient (GRG) method, Design applications. Quadratic Approximation Methods for Constrained Problems:- Direct quadratic approximation, Quadratic approximation of the Lagrangian function, Variable metric methods for constrained optimization. Structured Problems and SAlgorithms:-Integer programming, Quadratic programming, Complimentary pivot problems, Goal programming.

**MODULE V**

Comparison of Optimization Methods:- Software availability, Comparison philosophy, Classical comparative experiments. Strategies for Optimization Studies:- Model formulation, Problem implementation, Solution evaluation. Engineering Case Studies:- Optimal location of coal-blending plant by mixed-integer programming, Optimization of an ethylene glycol-ethylene oxide process, Optimal design of a compressed air energy storage system.

**REFERENCES:**

1. Ravindran. A, Ragsdell. K.M, Reklaitis. G.V.,Engineering Optimization- Methods and Applications. John Wiley & Sons 2006.
2. Kalynamoy Deb, “Optimization for Engineering Design, Algorithms and Examples”, Prentice Hall.
3. Hamdy A Taha, “Operations Research – An introduction”, Pearson Education.
4. Singiresu S Rao, “Engineering optimization Theory and Practice”, New Age International,

**MODEL QUESTION PAPER**

**MT 010 706L04 ENGINEERING OPTIMIZATION TECHNIQUES**

**PART A (5 X 3 =15 marks)**

1. What is an inflection point and how to identify it?
2. What is the function of the minimum-ratio rule in simplex method
3. Why must equality constraints be eliminated before applying direct search optimization methods
4. What is the difference between a goal and a constraint as used in goal programming?
5. Discuss optimization software and what are the measures of merit in selection of a particular software?

**PART B (5 X 5 =25 marks)**

1. Write short notes on simplex search method.
2. What are shadow [prices? What are their practical uses? What are opportunity costs?
3. Describe briefly the major differences between the MOM and other transformation methods such as SUMT
4. Explain the concept of “branching “ and “bounding” used in the branch-and-bound algorithm
5. Show that the problem

Minimize 

Subject to 



Attains its optimum value of f(x\*) = 3 at a family of points satisfying x1x2 =1 and 

**PART C (5 X 12 =60 marks)**

1. What is optimization? Give an example of optimization engineering design application

**OR**

1. Explain relationship of Marquardt’s method to Cauchy and Newton methods. Of the three which is preferred?
2. What are the practical uses of Kuhn-Tucker (i) necessity theorem and (ii) sufficiency theorem? State under what assumptions they are applicable.

**OR**

1. (a) What is saddlepoint solution? What is its significance in constrained optimization. (b) Under what conditions do saddlepoint solutions exist for NLP problems.
2. Outline a penalty-type SLP strategy that would exclude linear constraints and variable bounds from the penalty function construction. Discuss the merits of such a strategy

**OR**

1. What is the fundamental reason for placing bounds on the changes in the variables in the Griffith/Stewart direct linearization method?
2. (a) What is the major advantage of using an active constraint strategy? (b) how would such a strategy be used with the GRG method?

**OR**

1. Compare the treatment of inequality constraints in GRG and CVM algorithms. How do the method s of estimating multiplier values differ?
2. Discuss the case study of optimal design of a compressed air energy storage system

**OR**

1. Suggest a reformulation of the problem

Minimize 

Subject to 



All 

that would be easier to solve.

**MT 010 707 ELECTRO-METALLURGY LABORATORY**

**Teaching Schemes Credits:** 2

3 hours practical per week.

**Objective:**

The experiments are aimed at making the students familiar withtheprinciples of electrometallurgy .

**Suggested experiments**:

1. Experimental verification of Faraday’s laws.
2. Determination of throwing power of electrolytes.
3. Electro plating of copper.
4. Electro plating of Nickel.
5. Anodizing of Aluminium.
6. Stress-Corrosion Cracking of Steels.

**MT 010 708 METAL FORMING LABORATORY**

**Teaching Schemes Credits:** 2

3 hours practical per week.

**Objective:**

This laboratory course offers practical knowledge of forming of metals by plastic deformation.

**Suggested experiments**:

1. Open die (cold) Forging of Carbon and alloy steel pieces.
2. Evaluation of hardness, macro and microstructures of forged carbon and alloy steels.
3. Annealing and characterization w.r.t . hardness and microstructure of forged carbon and alloy steels.
4. Rolling of copper, brass, stainless steel and plain carbon steel using laboratory rolling mill,effect of strainrate studies on mechanical properties.
5. Microstructural analysis before and after rolling and annealing.

**MT 010 709 Seminar**

**Teaching scheme credits: 2**

2 hours practical per week

The seminar power point presentation shall be fundamentals oriented and advanced topics in the appropriate branch of engineering with references of minimum seven latest international journal papers having high impact factor.

Each presentation is to be planned for duration of 25 minutes including a question answer session of five to ten minutes.

The student’s internal marks for seminar will be out of 50. The marks will be awarded based on the presentation of the seminar by the students before an evaluation committee consists of a minimum of 4 faculty members. Apportioning of the marks towards various aspects of seminar (extent of literature survey, presentation skill, communication skill, etc.) may be decided by the seminar evaluation committee.

A bona fide report on seminar shall be submitted at the end of the semester. This report shall include, in addition to the presentation materials, all relevant supplementary materials along with detailed answers to all the questions asked/clarifications sought during presentation. All references must be given toward the end of the report. The seminar report should also be submitted for the viva-voce examination at the end of eighth semester.

**For Seminar, the minimum for a pass shall be 50% of the total marks assigned to the seminar.**

**MT 010 710 Project Preliminaries**

**Teaching scheme credits: 1**

1 hour practical per week

Project work, in general, means design and development of a system with clearly specified objectives. The project is intended to be a challenge to intellectual and innovative abilities and to give students the opportunity to synthesize and apply the knowledge and analytical skills learned in the different disciplines.

The project shall be a prototype; backed by analysis and simulation etc. No project can be deemed to be complete without having an assessment of the extent to which the objectives are met. This is to be done through proper test and evaluation, in the case of developmental work, or through proper reviews in the case of experimental investigations.

• The project work has to be started in the seventh semester and to be continued on to eighth semester

• Project work is to be done by student groups. Maximum of four students only are permitted in any one group.

• Projects are expected to be proposed by the students. They may also be proposed by faculty member (Guide) or jointly by student and faculty member.

• Students are expected to finalise project themes/titles with the assistance of an identified faculty member as project guide during the first week of the seventh semester.

The progress from concept to final implementation and testing, through problem definition and the selection of alternative solutions is monitored. Students build self confidence, demonstrate independence, and develop professionalism by successfully completing the project.

Each student shall maintain a project work book. At the beginning of the project, students are required to submit a project plan in the project book. The plan should not exceed 600 words but should cover the following matters. 

* Relevance of the project proposed 
* Literature survey 
* Objectives 
* Statement of how the objectives are to be tackled 
* Time schedule 
* Cost estimate

These proposals are to be screened by the evaluation committee (EC- minimum of 3 faculty members including the guide) constituted by the head of department, which will include a Chairman and the EC will evaluates the suitability and feasibility of the project proposal. The EC can accept, accept with modification, request a resubmission, or reject a project proposal.

Every activity done as part of project work is to be recorded in the project book, as and when it is done. Project guide shall go through these records periodically, and give suggestions/comments in writing in the same book.

The students have to submit an interim report, along with project work book showing details of the work carried out by him/her and a power point presentation at the end of the 7th semester to EC. The EC can accept, accept with modification, request a resubmission, or extension of the project.

The student’s internal marks for project will be out of 50, in which 30 marks will be based on day to day performance assessed by the guide. Balance 20 marks will be awarded based on the presentation of the project by the students before an evaluation committee consists of a minimum of 3 faculty members including the guide.

**For Project, the minimum for a pass shall be 50% of the total marks assigned to the Project work.**