M.Tech. Degree

INDUSTRIAL METALLURGY

SYLLABUS
FOR
CREDIT BASED CURRICULUM
(2011 - 2013)

Department of Metallurgical and Materials Engineering
National Institute of Technology
Tiruchirappalli - 620 015

JULY 2011
M.Tech. INDUSTRIAL METALLURGY

The total minimum credits required for completing the M.Tech. programme in Industrial Metallurgy is 67.

### SEMESTER – I

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Total Credits 67
ELECTIVES

I Semester
MT 613 Mechanical Behaviour of Materials
MT 617 Computational Techniques
MT 653 Materials Characterization
MT 665 Particulate Technology
MT 721 Stainless steel Technology
MT 723 Design of Castings & Weldments
MT 725 Ferrous Foundry Metallurgy

II Semester
MT 618 Metallurgical Failure Analysis
MT 622 Surface Engineering
MT 666 Total Quality Management
MT 674 Developments in Iron and Steel making
MT 722 Non Ferrous Foundry Metallurgy
MT 724 Advanced Materials and Processing
MA 613 ENGINEERING MATHEMATICS

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Partial Differential equations – basic concepts – One dimensional heat flow equation - Two dimensional heat flow equation in steady flow in Cartesian and Polar coordinates.

Calculus of variations - Euler’s equation - Variational problems in parametric form - Natural boundary condition – Conditional Extremum - Isoperimetric problems.

Numerical Solution of ODE’s – Euler’s, Taylor’s and Runge Kutta methods – Milne’s and Adams’ predictor-corrector methods.

Finite difference scheme for elliptic, parabolic, and hyperbolic partial differential equations.

Introduction to Finite Element Method - Rules for forming interpolation functions - Shape functions - Application to fluid flow and heat transfer problems.

TEXT BOOKS:
MT 651 PHYSICAL METALLURGY

(This is a core course for both WE, ME and IM specializations in MME)

Concept of phase diagram - phases and microconstituents in steels and cast irons - equilibrium and non-equilibrium cooling of various Fe-C alloys - effects of alloying elements and cooling rate on structure and properties of steels and cast irons

Introduction to heat treatment; TTT diagram and CCT diagram - hardenability measurement, annealing - normalising - hardening and tempering - heat treatment furnaces - atmospheres - quenching media - case hardening techniques

Introduction to specifications- types of steels: plain carbon steels, alloy steels, tool steels; stainless steels types of cast irons compositions, properties and applications, heat treatment (specific examples)

Aluminium and its alloys- physical, chemical and mechanical properties of aluminium of aluminium alloys, magnesium, titanium alloys - microstructural features, typical properties and applications - heat treatment (specific examples)

Copper and its alloys: physical, chemical and mechanical properties; classification of copper alloys; lead, tin, zinc, silver, gold alloys - microstructural features - properties and applications.

TEXT BOOKS:
Classification of welding processes; Gas welding; Arc welding; arc physics, power source characteristics,

Manual metal arc welding: Concepts, types of electrodes and their applications, Gas tungsten arc welding: Concepts, processes and applications; gas metal arc welding, Concepts, processes and applications, types of metal transfer, CO₂ welding, pulsed and synergic MIG welding, FCAW.

Submerged arc welding, advantages and limitations, process variables and their effects, significance of flux-metal combination, modern developments, narrow gap submerged arc welding, applications; electro slag and electro gas welding.

Plasma welding; Concepts, processes and applications, keyhole and puddle-in mode of operation, low current and high current plasma arc welding and their applications,

Resistance welding, Concepts, types and applications, Flash butt welding, Stud welding and under water welding

TEXT BOOKS:
Comparison of Solidification route with other manufacturing routes. Types, design of patterns, Allowances material selection, manufacture of patterns


Construction use and operation of electric arc furnace [Direct and Indirect Arc], resistance furnace - core and core less induction, cupola, rotary and crucible furnaces.

Layout, mechanisation and automation, fettling, inspection and pollution control.
Casting design, methoding, Gating and Risering calculations, improvement of yield and efficiency, simple problems in gating and risering for steels and cast irons. Solidification and simulation of metal casting

Casting defects Identification, analysis and Remedies

TEXT BOOKS:
List of Experiments
1. Study of metallurgical microscope and sample preparation
2. Microscopic examination of plain carbon steels,
3. Metallographic examination of cast irons
4. Metallographic examination of alloy steels
   • Stainless steels
   • Maraging steels
   • Tool Steels
5. Microscopic examination of Non Ferrous Metals and Alloys
   • Magnesium alloys
   • Aluminium alloys
   • Titanium alloys
   • Copper alloys
   • Super alloys
6. Microscopic Examination of Non Metallic Materials
MT 614 CORROSION ENGINEERING

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Principles of corrosion phenomenon: Thermodynamics and kinetics: emf/galvanic series, Pourbaix diagram, exchange current density, passivity, Evans diagram, flade potential.

Different forms of corrosion: atmospheric/uniform, pitting crevice, intergranular, stress corrosion, corrosion fatigue, dealloyming, high temperature oxidation-origin and mechanism with specific examples.

Corrosion testing and monitoring: Non-Electrochemical and Electrochemical methods: weight loss method, Tafel Linear polarization and Impedance techniques, Lab, semi plant & field tests, susceptibility test.

Corrosion prevention through design, coatings, inhibitors, cathodic, anodic protection, specific applications, economics of corrosion control.


TEXT BOOKS.

MT 702 SPECIAL CASTING PROCESSES

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Introduction to special casting techniques-Shell moulding machines - pattern equipments - sands, resins and other materials used in shell moulding - closing of shells - dimensional tolerances -applications of shell moulding - comparison of shell moulding with other competitive methods.

Types of centrifugal casting processes - calculation of mould rotary speeds - techniques and equipments used in production processes - advantages and limitations of centrifugal casting methods.

Introduction - Pattern and mould materials used in investment casting - technique and production of investment moulds and castings - dimensional tolerances - applications of investment casting process - Shaw process - comparison with other processes - full mould process.

Die casting machines - operation details - die materials - materials cast by die casting method. Die design - comparison with other processes. low pressure die casting. Metal Injection Moulding.

Fluid sand process - V Process - Rheo,thixo and compo casting processes - squeeze casting, Magnetic moulding, Hot box process, cold box process. No-bake processes, Graphite moulding process,Plaster moulding process-High Pressure moulding and continuous casting

TEXT BOOKS:

Texture effects. Metallurgical factors affecting recrystallization temperature and grain size. Effect of temperature, strain rate, hydrostatic pressure, Microstructure. Residual stresses, Friction and lubrication mechanisms. Lubricants in rolling, forging, extrusion, wire drawing, sheet metal forming. Tool design

Types of rolling mills, Geometrical factors and forces, Factors affecting rolling load and minimum thickness, Roll pass design, wheel and tyre production. Rolling defects, Processes and equipment, Forgeability, effect of various factors, definitions. Selection of equipment, die design, parting line, flash, draft, tolerance. Defects, causes and remedies.

High velocity forming methods, superplastic forming, hydroforming, isothermal forging. Principles and processes. FLD and LDR, CAD, CAM in forming use of softwares like OPTRIS, DEFORM, etc. Workability.


TEXT BOOKS:
Visual Inspection- tools, applications and limitations. Liquid Penetrant Inspection - principles, types and properties of penetrants and developers. Advantages and limitations of various methods of LPI. Magnetic particle inspection- principles, applications, advantages and limitations

Ultra sonic testing(UT) - Nature of sound waves, wave propagation - modes of sound wave generation - Various methods of ultrasonic wave generation, types of UT Principles, applications, advantages, limitations, A, B and C scan - Time of Flight Diffraction (TOFD)

Radiography testing (RT) – Principles, applications, advantages and limitations of RT. Types and characteristics of X ray and gamma radiation sources, Principles and applications of Fluoroscopy/Real-time radioscopy - advantages and limitations - recent advances.

Eddy current testing - Principles, types, applications, advantages and limitations of eddy current testing.


TEXT BOOKS:
List of Experiments

1. Tensile Testing
2. Hardness Measurements
3. Impact Testing
   All above tests will include ferrous and nonferrous alloys.
4. Determination of crystal structure parameters from XRD data
5. Scanning electron microscopy study: surface morphology, coating thickness measurement, fractured surfaces

MT725 SUMMER INDUSTRIAL TRAINING

Industrial training for one month in various metallurgical process industries during summer vacation period
MT 613 MECHANICAL BEHAVIOUR OF MATERIALS

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Strength of materials- basic assumptions, elastic and plastic behaviour, stress–strain relationship for elastic behaviour, elements of plastic deformation of metallic materials. Mohr’s circle, yielding theories

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

Ductile and brittle fracture, Charpy and Izod testing, significance of DBTT, ECT, NDT and FATT; elements of fractography - Griffith’s theory, LEFM– COD and J integral – determination of $K_{IC}$, COD and J integral

Characteristics of fatigue failure, initiation and propagation of fatigue cracks, factors affecting fatigue strength and methods of improving fatigue behaviour – testing analysis of fatigue data, mechanics of fatigue crack propagation, corrosion fatigue

Introduction to creep - creep mechanisms, creep curve, variables affecting creep, accelerated creep testing, development of creep resistant alloys, Larsen Miller parameter - Manson Hafred parameter

TEXT BOOKS:
MT 617 COMPUTATIONAL TECHNIQUES

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Design of Experiments: Factorial Design, Taguchi Techniques, ANOVA

Artificial Intelligence: ANN, fuzzy Logic, Genetic Algorithm, Applications in Materials Engg.,

Numerical Fluid Flow and Heat Transfer: Classification of PDE, Finite differences, Steady and unsteady conduction, explicit and implicit method

Finite element Methods: Introduction to I-D FEM; Problems in structural Mechanics using 2D elements, Plane stress, plain strain, axisymmetric analysis; three dimensional analysis.

Optimization Methods: Classical optimization methods, unconstrained minimization . Univariate, conjugate direction, gradient and variable metric methods, constrained minimization, feasible direction and projections. Integer and geometric programming

TEXT BOOKS:
3. Artificial Neural Networks - B. Yegnanarayana, Prentice-Hall of India, 1999
MT 653 MATERIALS CHARACTERIZATION

(This is a core course for both WE and ME specializations in MME)

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Numerical aperture, limit of resolution, depth of field and depth of focus - lens defects and correction - bright field and dark field illumination - polarised light, phase contrast, interference contrast, hot-stage, in-situ techniques, quantitative metallography

Powder, rotating crystal and Laue methods, stereographic projections and reciprocal lattice; X-ray residual stress measurement

Construction and operation and applications of TEM, specimen preparation techniques;

Construction and operation and applications of SEM, elemental analysis by WDS and EDS systems - analysis of fractured surfaces

X-ray fluoroscopy, spectrometry, Auger spectroscopy, DTA, DSC and TGA, working principle, applications. Types and applications of strain gauges.

TEXT BOOKS:
**MT665 PARTICULATE TECHNOLOGY**

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*Pre-requisite: MT 659 (Manufacturing Processes)*

Introduction to particulate processing – advantages, limitations and applications of particulate processing

Science of particulate processing – issues related to particle morphology – differences in mechanical behaviour (with respect to cast and wrought materials) and related mathematical treatment - similarities and differences between metal powder and ceramic powder processing

Production and characterisation of metal and ceramic powders – compaction processes – powder properties and powder compaction – Pressing, Hot Isostatic Processing and extrusion

Sintering – thermodynamic and process aspects – recent developments in mechanical alloying and reaction milling

Production of particulate composites - application of P/M based on case studies - manufacturing of typical products – near net shape processing

**TEXT BOOKS**

MT 721 STAINLESS STEEL TECHNOLOGY

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Atmospheric and Aqueous Corrosion, Stress-Corrosion Cracking and Hydrogen Embrittlement, High-Temperature Corrosion, Corrosion of Cast Stainless Steels, Corrosion of Weldments. ASTM and EN standards on corrosion resistance testing.

Forming, Forging and Extrusion, Heat Treatment, Machining, Welding, Brazing, Soldering and Adhesive Bonding, Surface Engineering.


TEXT BOOKS:


Types of joints, joint efficiency, edge preparation, types of loads, design for static loading, design for cyclic loading, rigid structures, primary and secondary welds, treating a weld as a line, structural tubular connections, influence of specifications on design, symbols for welding and inspection, estimating and control of welding costs. Residual stresses, causes and effects, methods to measure residual stresses, weld distortion.

Boiler and pressure vessel codes, structural welding codes, pipelines codes.

Welding procedure specifications, welding procedure qualifications, welder performance qualifications, welding variables, filler metal qualifications, qualification of welding inspectors, welding supervisors and welding engineers, qualification of NDT personnel.

**TEXT BOOKS:**

Iron-carbon and Iron-graphite equilibrium diagrams, phase changes in steels, effects of alloying element in steel, Solidification of steels and cast iron, and effect of mould materials and composition. Directional solidification of castings

Types of cast iron – Effect of normal elements in cast iron. Influence of composition and cooling rate. Cast iron production methods, SG Iron production – Degree of Nodularising – Malleable iron production, CG Iron, Austempered Ductile iron and Alloy Cast iron. Inoculation and Inoculating practices

Specifications for steels and alloy castirons as per IS, BS and ASTM. Metallurgical aspects of gating and risering of ferrous alloys, fluidity of ferrous alloys.

Melting furnaces and procedures used for ferrous castings; composition control, desulphurization, dephosphorization, melting of plain carbon steels, low alloy steels and stainless steels

Heat treatment of ferrous castings – Defects in ferrous castings, their causes and remedies

**TEXT BOOKS:**

Stages of failure analysis, classification and identification of various types of fracture. Overview of fracture mechanics, characteristics of ductile and brittle fracture.

General concepts, fracture characteristics revealed by microscopy, factors affecting fatigue life Creep, stress rupture, elevated temperature fatigue, metallurgical instabilities, environmental induced failure. Some case studies failures.


Causes of failure in forging, failure of iron and steel castings, improper heat treatment, stress concentration and service conditions. Failure of weldments - reasons for failure procedure for weld failure analysis.

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.

TEXT BOOKS:

MT622 SURFACE ENGINEERING

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Introduction tribology, surface degradation, wear and corrosion, types of wear, roles of friction and lubrication overview of different forms of corrosion, introduction to surface engineering, importance of substrate

Chemical and electrochemical polishing, significance, specific examples, chemical conversion coatings, phosphating, chromating, chemical colouring, anodizing of aluminium alloys, thermochemical processes industrial practices

Surface pre-treatment, deposition of copper, zinc, nickel and chromium principles and practices, alloy plating, electrocomposite plating, electroless plating of copper, nickel-phosphorous, nickel-boron; electroless composite plating; application areas, properties, test standards (ASTM) for assessment of quality deposits.

Definitions and concepts physical vapour deposition (PVD), evaporation, sputtering, ion plating, plasma nitriding, process capabilities chemical vapour deposition (CVD), metal organic CVD, plasma assisted CVD, specific industrial applications

Thermal spraying, techniques, advanced spraying techniques plasma surfacing, D-Gun and high velocity oxy-fuel processes, laser surface alloying and cladding, specific industrial applications, tests for assessment of wear and corrosion behaviour.

TEXT BOOKS:
Definitions of the terms - quality, quality planning, quality control, quality assurance, quality management, Total Quality Management (TQM) as per ISO 8402 - overview on TQM - The TQM axioms - Commitment - Scientific knowledge - Involvement - Consequences of total quality-Deming’s fourteen points on quality management - five DDs - implementing the Deming philosophy - action plan - the Deming cycle - questions and opinions of Deming.

Developing a habit of quality - Juran quality trilogy - the universal break through sequence - comparison Juran and Deming approaches-Crosby's diagnosis of a troubled company - Crosby's quality vaccine - Crosby's absolutes for quality management - Crosby's fourteen steps for quality improvement.

Meaning - Kaizen and innovation - the Kaizen management practices - total quality control (TQC) - approaches of Faigenbaum, Ishikawa - Kaizen and TQC - Kanban systems - small group activities - quality control circles - suggestion systems - comparison of Kaizen and Deming’s approach.

Affinity diagram - bar chart - block diagram - brainstorming - cause and effect analysis - customer-supplier relationship checklist - decision analysis - flow charts - force field analysis - line graph/run charts - Pareto analysis - quality costing - Quality Function Deployment (QFD) - quality project approach and the problem solving process.

The structure of ISO 9000 series quality system standards - certification process - action plan development for cases-Integrating quality into strategic management - Quality and the management cycle - Resources for Quality activities - Training for Quality - Self Managing Teams - Role of the Quality Director - Obstacles to achieving successful Strategic Quality Management.

TEXT BOOKS :
Principles of ferrous process metallurgy; review of related concepts from metallurgical thermodynamics and kinetics; sequence of operations in steel plants; basic aspects of furnaces, refractories and fuels; differences between the production of carbon steels and highly alloyed steels

Overview of iron making, steel making, refining and continuous casting processes; indicative process calculations; environmental considerations; quality issues in steel plant operations

Modifications of steel making converter operations; developments such as sub lance and dynamic control of steel making, secondary treatment including ladle metallurgy and injection metallurgy; continuous steel making; illustrative numerical problems

Modifications of continuous casting process; developments such as flow control devices in tundish, sequence casting, high speed casting, detection / prevention of caster breakouts, electromagnetic stirring, thin slab casting; strip casting; illustrative numerical problems

Current research on metallurgical slags, measurement of critical properties, use of process modeling; design and selection of slags and refractories; discussion on related binary and ternary phase diagrams

**TEXT BOOKS**

1. Current literature on related topics
Structure of liquid metals, macrostructure of pure metals and alloys - Typical casting alloys, specifications, properties, industrial applications, melting and composition control, deoxidation, gating and risering techniques.

Typical casting alloys, specifications, properties, industrial applications, melting and composition control, deoxidation, gating and risering techniques.

Typical casting alloys, specifications, properties, industrial applications, melting and composition control, deoxidation, gating and risering techniques - Typical casting alloys, specifications, properties, industrial applications, melting and composition control, deoxidation, gating and risering techniques.

Basic principles of deoxidation.

TEXT BOOKS:
Introduction to advanced ceramics and metallic materials-advantages


Pure metals, alloys, intermetallics, immiscible alloy systems and composites; their preparation and applications


Consolidation techniques for ceramics and metallic powders-Die compaction -Hot pressing, Cold and Hot Isostatic Pressing, Powder extrusion, Equal Channel Angle Process

TEXT BOOKS: