M.Tech. Program on Steel Technology

Offered by:

Department of Metallurgical Engineering and Materials Science

IIT Bombay, Powai, Mumbai 400 076

Background

The Indian steel industry is witnessing a rapid growth since 2001. It is expected that by 2012 India would be the second largest steel producer globally. In order to maintain global leadership as well as produce the best quality steel at the lowest cost, it is imperative that well trained manpower is available on a continual basis to the industry. Presently, there is a huge gap between the growing need for well trained quality manpower and its availability, both globally and within the country. In addition, there are challenges in developing low energy and environmentally friendly technology for producing steel. In order to address this issue of large demand in highly qualified manpower in steel, IIT Bombay is launching the new M.Tech. program on **Steel Technology**.

The new M.Tech. program on **Steel Technology** aims at developing strong fundamentals and analytical skills in professionals working in the industry, which would make them specially suited for taking up technological challenges faced by the steel industry. The detailed curriculum of this program has been developed based on interaction and feedback received from industry experts, academia and the steel ministry representatives.

Curriculum Structure

The M.Tech. program will have **seven compulsory (core) theory** courses and two laboratories. The candidates will also register for a **seminar course and a course on communication skills**. In addition, the candidates need to select and register for **four elective courses** from the list of electives provided. The list of core courses is given below and the list of electives is provided in Appendix 1.

Core / Compulsory Courses

MM 651	Thermodynamics of Materials
MM 659	Transport Phenomena
MM 451	Instrumentation & Process Control
MM 621	Advanced Physical and Mechanical Metallurgy
MM 622	Advanced Concepts in Iron Making
MM 624	Advanced Concepts in Steel Making
MM 626	Thermo-Mechanical Processing and Forming of Steel
MM 611	Processing and Characterization of Steel – Laboratory Course
MM 612	Computational Laboratory
MM 694	Seminar
HSS 699	Communication Skills

The entire course work will be over in the first year of the M.Tech program. The second year, including the summer term, will be exclusively for carrying out the M.Tech. Project work. The description of all the courses is presented in Appendix 2.

Eligibility Criteria and Selection Procedure

All candidates seeking admission to this program must have B.Tech / B.E. or equivalent in Metallurgical or Mechanical or Chemical Engineering with FIRST class (60%) (55% for SC/ST). The candidates must have either a valid GATE score or 2 years relevant professional experience. The candidates must be from recognized industrial organizations / academic institutions. Interested candidates should send a fully completed application form to reach us on or before June 16, 2008. Candidates will be selected based on the performance in an interview to be conducted during the last week of June 2008.

Fee Structure and Accommodation

The fee for this program will be Rs 2.0 lacs per year (excluding the hostel rent/fee and mess expenses). The total fee will be Rs 4.0 lacs for the entire M.Tech. program (excluding hostel rent /fee and mess expenses). **Student hostel accommodation (possibly on sharing basis) may be provided at the time of admission depending on the availability and the fee for this would be as per existing norms of the institute. It should be noted that no special or executive type accommodation is available at IIT Bombay.**

For any other details pertaining to the M.Tech. program on Steel Technology, please contact: Convener, M.Tech in Steel Technology, Dept. of Metallurgical Eng. & Mat. Sci., IIT Bombay, Powai, Mumbai 400 076, Ph: 022-2576 7630, email: steel-tech@met.iitb.ac.in

Appendix 1

List of Elective Courses

Appendix 1

List of Elective Courses

(a) Autumn Semester

MM 647	Numerical Methods in Materials Processing
MM 653	Characterization of Materials
MM 655	Modeling and analysis
MM 670	Powders and sintered products
MM 680	Welding Science and Technology
MM 681	Plastic Deformation and Microstructure Evolution
MM 691	Topics in Phase Transformation

(b) Spring Semester

MM 630	Mineral Process Engineering
MM 632	Surface Engineering
MM 656	Simulation and Optimization
MM 658	Fracture Mechanics and Failure Analysis
MM 668	Computational Methods for Metal Forming Analysis
MM 672	Solidification Processing
MM 682	Grain Boundaries and Interfaces
MM 684	X-Ray Diffraction and Electron Microscopy
MM 686	High Temperature Materials

(c) Outside Dept. Courses

CR 615	Introduction to Corrosion
ES 601	Environmental Chemistry
ES 629	Principles of Environmental Engineering
ME 613	Finite Element and Boundary Element Methods
CE 620	Finite element methods
CL 603	Optimisation
CL 605	Advance Reaction Engineering
CL 712	Process Data Analysis and Design of Experiments

Appendix 2

Detailed Course Contents

Appendix 2

Core (Compulsory) Course Contents

MM 451 Instrumentation and Process Control Theory

Modelling in mechanical translation, Rotary and simple hydraulic and pneumatic systems, One tank and two tank process, Block diagrams, transfer functions and steady state behaviour of systems. Dynamic behaviour, transient response and analysis, stability criterion. Types of controllers on-off, P, PI, PID controllers. Analog computers and their use in simulation and analysis of control systems. Digital control, programmable logic controllers, Radder diagrams. Characteristics of measurements, temperature measurement, flow measurement, pressure measurement and level measurement. Measurement of force and torque. Measurement of acceleration. P & ID of typical processes Case examples in instrumentation from materials processes.

Texts/References:

F.H. Raven, Automatic Control Engineering, McGraw-Hill, 1995.

B.C. Nakra and K.K. Chaudhry, Instrumentation, Measurement and Analysis, Tata McGraw Hill,
1985.

D.P. Eckman, Industrial Instrumentation, Wiley Eastern, 1985.

MM 611 Processing and Characterization of Steel - Laboratory Course

Experiments involving processing, structural characterization and property evaluation of steel. The topics that would be covered are : Processing: melting and casting, heat treatment, thermo-mechanical processing, sheet metal forming and welding. Structural characterization: phase transformation, electron microscopy, crystallography by using modern techniques. Properties: mechanical properties (like fatigue, fracture toughness, integrity assessment) relating to structure and processing, corrosion evaluation.

Texts / References

K.Tien and J.F.Elliott (eds), Metallurgical Treatises, Metall. Soc. AIME, 1981

G.E.Dieter, Mechanical Metallurgy, McGraw-Hill Book Co. (Third edition), 1988.

K. W. Andrews, Physical Metallurgy Techniques and Applications, Vol. 1 and 2, George Allen & Unwin, London, 1973

E. N. Kaufmann (Ed. in chief), Characterisation of Materials, Vol 1. and 2, John Wiley and Sons Publication, New Jersey, 2003.

MM 612 Computational Laboratory

Examples of computer applications for solving mathematical equations. The lab will involve development of programs based on numerical methods and statistical techniques for solving variety of common metallurgical and materials engineering problems. Typical examples: program for solving system of linear equations; case study based on material and heat balance in a metallurgical process. Program for regression analysis and curve / function fitting to a given data set; case study illustrating regression analysis. Program for root finding on non linear equation; case study for root finding. Program for solving differential equations based on Rungekutta formulation; case study illustrating use of differential equations examples – Decarburization in an LD vessel; Linear programming problem for optimization.

Texts / References**:**

S.C. Chapra and R.P. Canale, Numerical Methods for Engineers, Fifth Edition, Tata McGraw Hill, New Delhi, 2007.

MM 621 Advanced Physical and Mechanical Metallurgy

Microstructure & Properties: solidification and solidification structures, interfaces, crystallographic texture, residual stress, structure-property relations. Plasticity and work hardening: fundamentals, stress-strain behavior, fracture, creep & deformation mechanisms. Recovery, recrystallization, grain Growth. Phase transformation: thermodynamic basics, nucleation and growth, spinodal decomposition, martensitic transformations.

Texts/References**:**

T. H. Courtney, Mechanical Behavior of Materials, McGraw-Hill, 2nd Edition, (2000).

R. W. Cahn, P. Haasen and E. J. Kramer, (Eds.), Materials Science and Technology: A Comprehensive Treatment, VCH, Weinheim, Germany, (1993).

R.E. Smallman and A.H.W. Ngan, Physical Metallurgy & Advanced Materials, Elsevier, 7th Edition, (2007).

Martin J.W., Doherty R.D. and Cantor B., 'Stability of microstructures in metallic systems', 2nd Edition, Cambridge University Press, UK, (1997).

Porter D.A. and Easterling K.E., 'Phase Transformations in Metals and Alloys', Van Nostrand Reinhold, UK, (1986).

Calladine C.R. "Plasticity for Engineers – Theory and Applications" Horwood, Chichester, England, 2000.

B. Verlinden, J. Driver, I. Samajdar, R. D. Doherty, Thermo-Mechanical Processing of Metallic Materials, ISBN 978-0-08-044497-0, Pergamon Materials Series, series ed. R.W. Cahn, Elsevier, Amsterdam, 2007.

MM 622 Advanced Concepts in Iron Making

Thermodynamics of C-O, Fe-O, C-O-Fe and C-O-Fe-H2 systems. Models for gas-solid reaction kinetics. Blast furnace reactions and process dynamics; models for the blast furnace; agglomeration: sintering and pelletization –mechanisms; blast furnace aerodynamics; irregularities.

Direct reduction : gas-based and coal based; reactions in Midrex/Hyl processes, rotary kiln processes and operational difficulties. Smelting reduction-COREX process.

Advances in processes through term papers.

Texts / References

J. C. Peacey, W. G. Davenport, The Iron Blast Furnace: Theory and Practice, Pergamon.

A. Chatterjje, Beyond the Blast Furnace, CRC Press, 1994.

Making, Shaping and Treating of Steel, Vol.1:Ironmaking, 11 th Edition, AISE Steel Foundation, 1999.

A.Ghosh and A.Chatterji, Ironmaking and Steelmaking : Theory and Practice, Prentice- Hall of India Private Limited, 2007.

MM 624 Advanced Concepts in Steel Making

Review of thermo : solutions, change of standard states, activity interaction parameters. Reactor models : CSTR and plug flow reactors, residence time distributions; Structure and thermodynamics of slags.

C-O, Si-O, Mn-O reactions, reactions of S and P, sulphide and phosphate capacities. Oxygen steelmaking : design parameters for vessel and lance, material and heat balances. Process dynamics, static dynamic and process models, process control. Electric arc furnace : reaction mechanisms, material and heat balances, equipment design principles.

Ladle metallurgy; Deoxidation : thermodynamic and kinetic analysis, inclusion shape control. Secondary and alloy steel making: thermo. and kinetic analysis, model building.

Continuous casting: solidification mechanisms and structure, fluid flow and heat transfer in tundish and strand, physical and mathematical models, understanding defects, recent developments.

Refractories and phase diagrams.

Texts / References

Making, Shaping and Treating of Steel, Vol.1:Ironmaking, 11 th Edition, AISE Steel Foundation, 1999.

A.Ghosh and A.Chatterji, Ironmaking and Steelmaking : Theory and Practice, Prentice- Hall of India Private Limited, 2007.

F.D. Richardson : Physical Chemistry of Melts in Metallurgy, Academic Press, 1974.

T.A.Engh, Principles of Metal Refining, Oxfird Iniv.Press, 1992.

MM 626 Thermomechanical Processing and Forming of Steel

Forming techniques: rolling, extrusion, wire drawing, forging, pilgering, sheet metal forming, hydroforming, superplastic forming, Defects in TMP: form defects, surface defects, fracture related defects, strain localizations. Physical simulation of properties: tensile and compression testing, hot torsion tests, mixed strain path tests, typical formability tests. Case studies: steel for car body, dual phase and TRIP steel, controlled rolling of HSLA, electrical steel, patented steel wire.

Texts / References

Dieter G., 'Mechanical Metallurgy', McGraw-Hill, (1976).

B. Verlinden, J. Driver, I. Samajdar, R. D. Doherty, Thermo-Mechanical Processing of Metallic Materials, ISBN 978-0-08-044497-0, Pergamon Materials Series, series ed. R.W. Cahn, Elsevier, Amsterdam, 2007.

Metals Handbook – Forming and Forging, vol. 14, Ninth Edition, (1988), ASM, Ohio, USA.

Kalpakjian S., 'Manufacturing engineering and technology', Addison-Wesley (1995).

MM 651 Thermodynamics of Materials

Simple and composite systems, stable equilibrium states. Adiabatic work interaction, heat interaction, internal energy, First law. Reversible processes, heat engines, Second law, Theorem of Clausius, entropy, combined first and second law. Legendre Transforms, representations of the fundamental equation. Equilibrium: extremum principles, membrane, phase and reaction equilibria. Single phase systems: Thermodynamic relations among variables. Solutions, partial molal properties, solution models. Phase rule, unary, binary and ternary phase diagrams. Thermodynamics of phase diagrams. Reacting systems, gas phase reactions, Ellingham diagrams, Pourbaix diagrams.

Texts/References

M. Modell and R.C. Reid, Thermodynamics and its applications, Prentice Hall, Englewood Cliffs, NJ 1983.

H.B. Callen, Thermodynamics and an Introduction to Thermostatics, Jonh Wiley, NY 1985.

R.T. DeHoff, Thermodynamics in Materials Science, McGraw Hill, Singapore, 1993.

MM 659 Transport Phenomena

Continuum hypothesis, Energy balance, Bernoullis principle. Basic definitions in flows, viscosity, shear stress as momentum flux. Shall balances. Friction and friction factor, concept of hydraulic radius, packed and fluidised beds. Compressible flow through pipes and nozzles. Differential balances, equation of continuity, Navier-Stokes equation. Three modes of heat transfer, Conduction laws, resistance, fins, transient conduction, lumped parameter systems, Heissler charts. Convection, boundary layer and equation of heat transfer, forced and natural convection. Radiation and view factors, effect of absorbing media. Basic equation of mass transfer, convective mass transfer, analogy between heat and mass transfer, convective mass transfer relations.

Texts/References

R.B. Bird, W.E. Stewart and E.N. Lightfoot; Transport Phenomena, McGraw-Hill, N.Y., 1960.
Frank P. Incropera & David P Dewitt , Fundamental of Heat and Mass Transfer, John Wiley, 5th Edition, 2002.

Course Contents (Electives)

DEPARTMENTAL COURSES

MM 630 Mineral Process Engineering

Ore handling, metallurgial accounting and control. Particle size analysis. Communution, liberation, crushers, grinding mills, industrial screening, classification, gravity concentration, heavy media separation. Froth flotation, magnetic and high tension separation, dewatering, tailings disposal, process integration and flow-sheet analysis.

Texts / References

B.A.Wills, Mineral Processing Technology (5th Edition), Pergamon Press, 1992.

E.G.Kelly and D.J.Spottiswood, Introduction to Mineral Processing, John Wiley & Sons, 1982.

A.M.Gaudin, Principles of Mineral Dressing, Tata-McGraw Hill, 1974.

MM 632 Surface Engineering

Importance of surface engineering for materials development. Rationale in selection of surface engineering methods. Surface preparation techniques for various coating methods. Various coating techniques: painting, electro and electroless plating, hot-dip coating and thermal spray, CVD, PVD and coatings and laser and electron beam assisted coatings and processes. Surface modification through conversion, anodizing, carburizing, nitriding, ion implantation etc. Continuous coating processes for sheets and coils. Case studies. surface and coating characterization.

Texts / References

Surface Engineering, ASM Handbook Volume 5, Ohio, 1994

R.Lambourne and T.A.Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.

C.G.Munger., Corrosion Prevention by Protective Coatings Publications, NACE, Houston, 1984.

J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press Ltd., 1976.

F.A. Lowenheim, Electroplating: Fundamentals for Surface finishing, McGraw Hill, New York, 1978

MM 647 Numerical Methods in Materials Processing

Review of basic numerical methods like root finding, numerical integration, solving systems of equations, multiple linear regression etc. with special emphasis on computer implementation and applications in materials processing.

Initial and boundary value problems, partial differential equations. Introduction to finite difference (FDM) and finite element (FEM) methods.

Applications in materials processing: heat transfer and solidification; metal forming processes: analysis of sheet necking, formability tests and forming limit diagrams (FLD)

Texts / References

Numerical methods for engineers: With personal computer applications, Steven C. Chapra and Raymond P. Canale, McGraw-Hill (International Edition), 1990.

Metal forming and finite element method, S. Kobayashi, Y. T. Im and T. Altan, Oxford Univ. Press, New York, 1989.

Process modelling of metal forming and thermomechanical treatment, C. R. Boer, N. Rebelo, H. Rydstad and G. Schroder, Springer-Verlag, 1986.

MM 653 Characterization of Materials

Stereographic Projections, X-ray diffraction, crystal structure and phase identification, residual stress measurement and other applications. Outline of thermal analysis technique, description of DTA/DSC/TGA techiques and instrumentation, applications and case studies. Optical microscopy – light optics, microscope components, possibilities and limitations. Scanning Electron Microscopy – Optics and performance of a SEM, Image interpretation, crystallographic information in a SEM, analytical microscopy. Transmission Electron Microscopy – Construction and operation of a TEM, Electron diffraction, Image interpretation.

Texts/References

Metals handbook Vol.9 "Characterisation of Materials", 10th Edition, American Society of Metals, Metals Park, OH, USA, 1986.

H.H. Willard, L.L. Merrit, J.A. Dean and F.A. Settle, "Instrumental Methods of analysis", 6th Edition, CBS Publishers & Distributors, Delhi, 1986.

MM 655 Modelling and Analysis

Role of models in process engineering. Model classification. Modelling procedure. Conservative and constitutive equations. Dynamic models lumped parameter and distributed parameter models. Solution strategies. Sensitivity analysis. Data acquisition, analysis and model validation. Examples from materials processing.

References

K.M. Hangos and I.T. Cameron, Process Modeling and Model Analysis, Academic Press, London, 2001.

R. Aris: Mathematical Modelling Techniques, Dover, New York, 1994.

R. Aris: Mathematical Modelling A Chemical Engineers Perspective, Academic Press, Florida, 1999.

MM 656 Simulation and Optimisation

Linear programming models and applications, simplex algorithm for linear programming. Geometry of simplex algorithm, Duality and sensitivity analysis. One dimensional minimization, Febonacci, Golden section and Quadratic interpolation methods, Unconstrained optimization, Univariate, Conjugate direction, gradient projection methods. Experimental design-Orthogonal Matrix, Factorial Design, Taguchi Techniques. Error Analysis. Next event simulation, satistical analysis of results, monte-carlo simulations, logical and statistical validity. Simulation of heat and mass flow problems, application to metal forming. Simulation of tensile testing of materials.

Texts/References

S.S. Rao, Optimisation – Theory and applications, Wiley Eastern Ltd., 1978.

R.L. Fox, Optimization Method for Engineering Design, Addison Wesley, 1970.

JM. Kupfer Schmind and J.G. Ecker, Introduction to Operations Research, John Wiley & Sons, 1988.

MM 658 Fracture Mechanics and Failure Analysis

Fracture Criteria, Introduction to linear elastic fracture mechanics, Analysis of simple crack problems. Nucleation and propagation of cracks. Correlation between microstructure and fracture behaviour in different materials. Mechanisms of fracture. Evaluation of fracture toughness. Crack behaviour in elastic plastic materials. Effect of strain rate, environments temperature, irradiation etc. on fracture behaviour of materials. Conventional approach to fatigue crack growth in reactive environments static or cyclic loading. Applications of fracture mechanics to materials selection, alloy design, design of structures and failure analysis.

Text/References

S.T.Rolfe and J.M.Barsom, Fracture and Fatigue control in structures, Prentice Hall, 1972.

David and Bruck, Elementary Egnineering Fracture Mechanics, Norelho, 1975.

Case Histories in Failure Analysis, ASM, Ohio, 1979.

MM 668 Computational Methods for Metal Forming Analysis

Description of generalized stress / strain behaviour. Principal quantities; Mohrs circle; Elastic Vs plastic deformation.

Theories of yielding; Analysis of metal forming processes by ideal work, upper bound and slab methods. Analytical modeling approach for simulating axi-symmetric deep drawing process. Concept of formability and forming limit strains. Applications of computational methods for metal forming analysis. Application of FE based programs for metal forming analysis.

Experimental measurements of loads and strains during tensile and formability testing of variety of materials (low carbon steel, aluminum and stainless steel).

Development of a computation model for tensile test simulation and its validation. Simulation of tensile and metal forming tests using computational programs based on finite element methods. Comparison of computed results with the experimentally measured data.

Simulation and validation of industrial metal formed components.

Texts / References

R. H. Wagoner, J. L. Chenot, Metal forming analysis, Cambridge University Press, 2001.

W. F. Hosford and R. M. Caddell, Metal forming: mechanics and metallurgy, Second Edition, Prentice-Hall, 1993.

G. W. Rowe, C. E. N. Sturgess, P. Hartley and I. Pillinger, Finite element plasticity and metal forming analysis, Cambridge University Press, 1991.

C. R. Calladine, Plasticity for engineers, Ellis Horwood, 1995.

MM 670 Powders and Sintered Products

Preparation of metallic, ceramic and composite powders. Mechanical, solid state and solution, methods. Powder Characterization:-Particle size, shape. Distribution, surface area, structure, morphology and composition. Shape Forming: Uniaxial and isostatic compaction, xtrusion, injection moulding, tape forming, slip casting and sol-gel casting etc. Powder coating on substrates. Flame and plasma spraying, electrophoresis, electrodeposition, sol-gel coating etc. Sintering: Solid state sintering, liquid phase sintering, reaction sintering, hot pressing, hot isostatic pressing and self propagating combustion sintering.

Texts/References

W.D. Kingery, H.K.Bown and D.R.Uhlmann, Ceramic Science & Technology, John Wiley & Sons, New York, 1976.

F.F.Y. Wang, Ceramic Fabrication Processes, Academic Press, 1976.

I. Jenkins and J.Wood, Powder Metallurgy: An Overview, Institute of Metals, London, 1991.

R.M. German, Powder Metallurgy Science, Metal Powder Industries Federation, Princeton, New Jersey, 1984.

MM 672 Solidification Processing

Introduction to solidification, rapid solidification, Methods of rapid solidification, rapid quenching, bulk undercooling, Structure and properties of liquid, kinetics of liquid state, Nucleation-basic concept, steady state nucleation, Undercooled liquid properties, thermodynamics, kinetic parameters. Crystal Growth, growth equation, growth under rapid solidification, pure elements and dilute alloys (collision limited growth), microstructural modification, absolute stability, microstructural modification, absolute stability, solute trapping, eutectic solidification, peritectic solidification, Metastable phase diagrams, construction of principles, Metallic glasses or amorphous materials, criteria for glass formation, TTT and CCT curves for glass formation, overview applications.

Texts/References

W. Kurz and D.J. Fisher, Fundamentals of Solidification, Trans. Tech. Publications, Switzerland, 1984.

M.C. Flemings, Solidification Processing, McGraw Hill, New York 1974.

International Materials Reviews, Materials Science & Engineering, Acta Materialia- Journals.

MM 680 Welding Science and Technology

Overview of welding processes, study of welding arc characteristics, metal transfer during arc welding, heat flow during welding, gas-metal and slag-metal reactions, weldpool solidification, effect of welding process parameters on the macro- and micro-structure of weld metal. Thermal cycles in the heat affected zone. Phase transformations in the weld metal and the heat affected zone. Phenomena of hot-cracking and cold cracking. Residual stresses and distortion during and after welding. Application of above principles to welding of carbon and alloy steels, cast rions, stainless steels, aluminium and titanium alloys. Fatigue and fracture of weldments.

Texts/References

K.Easterling, Introduction to Physical Metallurgy of Welding, Butterworths Publication, 1983.

Sindo Kou, Welding Metallurgy, John Wiley, 1987.

S.A.David, Ed.; Advances in Welding Science and Technology, American Society for Metals, Ohio, 1986.

MM 681 Plastic Deformation and Microstructure Evolution

Molecular theory of deformation kinetics. Rate theory of plastic deformation. Micromechanistic approach for deformation behaviour of single crystals and polycrystals. Low temperature deformation of metals and other crystalline solids. Dynamic strain ageing, creep, internal stress. Deformation of intermetallic compounds. Substructural evolution at large strains. Recovery, recrystallization and grain growth during high temperature deformation. Formation of cell boundaries, slip in a cell structure and composite model of time dependent flow.

Texts/References

R.W.Cahn, P.Haasen and E.J.Kramer (eds), Materials Science and Technology, Vol.6, Plastic Deformation and Fracture of Materials, H.Mughrabi (vol. ed), VCH, 1993.

G.Krauss (ed.), Deformation, Processing and Structure, ASM, 1984.

S.Krausz and H.Eyring, Deformation Kinetics, John Wiley and Sons, 1975.

T.N. Baer (Ed.,), Yield, Flow and Fracture of Polycrystals, Applied Science Publishers Ltd., 1983.

R.J. Arsenault (Ed.) Plastic Deformation of Materials : Treatise on Materials Science and Technology, Vol.6, Academic Press, 1975.

MM 682 Grain Boundaries and Interfaces

Phenomenology of solid interfaces and solid interfacial energies. Structural models for grain- and interphase-boundaries. Determination of interfacial energies. Interfacial characterization. Grain boundary segregation. Role of interfacial phenomena in deformation and failure of materials. Interfacial phenomena in thin films and composite materials.

Texts/References

L.E. Murr, Interfacial Phenomena in Metals and Alloys, Addison-Wesley, 1975.

G.A.Chadwick and D.A.Smith (Ed.), Grain Boundary Structure and Properties, Academic Press, 1976.

R.W. Balluffi, Grain Boundary Structure and Kinetics, ASM, Ohio, 1980.

M.E. Kassner and T.G. Langdon (Guest eds), Mater. Sci. Eng., A, Vol. concepts A166, 1993.

MM 684 X-Ray Diffraction and Electron Microscopy

Introducltion to X-rays, filters. Atomic Scattering factors and structure factor. Intensity Calculations. Reciprocal Lattice. Ewald spehre construction. Techniques for structure determination. Point groups. Space groups. Systematic absences due to symmetry elements. Wyckoff Notation. Fourier series methods. Phase prolem. Patterson Function. Heavy atom methods. Anamolous scattering. Finite size effects. Intensity distribution in reciprocal space. Particle size determination for polycrystalline samples.

Introduction to electron microscopy, electrons and their interactions with the specimen, electron diffraction. TEM-construction, contrast mechanisms and some applications. Analytical microscopy. SEM.

Texts/References

L.C. Azaroff, Elements of X-ray Crystallography, McGraw Hill, NY, 1968.

F.D. Bloss, Crystallography and Crystal Chemistry, Holt, Rinehart and Winston, NY, 1971.

G. Thomas and M.T.Goringe, Transmission Electron Microscopy of Materials, John Wiley, 1979.

M.V. Heimendahl, Electron Microscopy of Materials - An Introduction, Academic Press, 1980.

MM 686 High Temperature Materials

Design considerations at elevated temperatures. Reactivity of solids. Creep-rupture behaviour. Fatigue at elevated temperatures. Stability of materials in service environments. High

temperature materials. Refractory metals and alloys. Superalloys, high temperature ceramics, cermets and ceramic coatings. Processing of high temperature materials. Modern melting and solidification techniques. Powder metallurgy techniques. Thermomechanical treatments.

Texts/References

P.R .Sahm and M.O.Speidel, High Temperature Materials in Gas Turbines Ed. Elsevier, 1974.

W.D. Kingery, Introduction to Ceramics, John Wiley and Sons, 1960.

F.F.Y. Wang, Ceramic Fabrication Processes, Academic Press, 1976.

R.M. German, Powder Metallurgy Science, Metal Powder Industries Federation, Princeton, New Jersey, 1984.

MM 691 Topics in Phase Transformations

Gibbs free energy composition diagrams, Analysis and synthesis of phase diagrams. Solid-solid nucleation theory. Interface and diffusion controlled growth. Thermodynamics and Kinetics of phase separation. Order-disorder transformations. Crystallography of martensitic transformation. Transformations in rapidly solidified alloys and glasses. Phase stability in advanced ceramics. High pressure phase transformations. Phase Transformations in Steels.

Texts/References

H.I. Aaronson (Ed.), Lectures on the Theory of Phase Transformations, The Metallurgical Society (AIME), Warrendale, Pennsylvania, 1975.

J.W. Christian, 'Theory of Transformations in Metals and Alloys', Pergamon Press, 1965.

P. Haasen (Ed.), Phase Transformations in Materials, VCH Publishers Inc, New York, 1991.
T.J. Gray and V.D. Frechette. Kinetics of Reactions in Ionic Crystals, Plenum Press, 1969.

A.G. Khachaturyan, Theory of Structural Transformations in Solids, Wiley Interscience Publishers, 1983.

A.M. Alper, Phase Diagrams: Material Science and Technology, Vol.6, Academic Press, 1978.

Electives Course Contents (From Other Departments)

CR 615 Introduction to Corrosion

Importance of Corrosion, Computation of Corrosion rates, Thermodynamics of Corrosion, Passivation, Mixed potential theory of corrosion and its application to understand the influence of oxidizers, effect of velocity of the medium, galvanic corrosion: area relationship in both active and passive states of metals. \015\012Different forms of corrosion and their control viz., uniform corrosion, galvanic corrosion, selective leaching, crevice corrosion, filiform corrosion, pitting corrosion, intergranular corrosion, erosion corrosion, fretting damage, stress corrosion cracking, corrosion fatigue, hydrogen embrittlement and microbes induced corrosion. Elementary treatment of corrosion testing procedures, inhibitors, corrosion of steels

Texts/Reference

G. Fontana, Corrosion Engineering, Mars., McGraw Hill, 3rd edition, Singapore, 1987.

H.H. Uhlig and R.W. Revie 3rd edition, Corrosion and its control, John Wiley, Singapore, 1991.

ES 611 Environmental Chemistry

Acquatic Chemistry : Chemistry equilibria and kinetics fundamentals; Acids and bases; Titrations; Acidity; Alkalinity; Buffers and buffer intensity; Chemical equilibrium calculations; pC-pH diagram. Precipitation and dissolution; Water softening and water conditioning; Langelier index; Solubility diagram; Coexistence of phases in equilibrium; Complixation of metal ions and organic complexes in natural water. Oxidation and reduction reactions stoichiometry; Redox couples; pE-pH diagrams; Redox control in natural systems; Basic concepts of organic and colloid chemistry. Soil Chemistry : Weathering reactions; Structure and surface reactions of clays and oxides; Forces at soil-water interfaces. Atmospheric Chemistry : Chemical equilibria and kinetics; Photo-dissociation and free radical reactions; Chemistry of precipitation; Acid rain.

Texts/References

Sawyer,C.N., McCarty,P.L., and Parkin,G.F., Chemistry for Environmental Engineering, McGraw-Hill, Inc., New York, 1994.

Manahan,S.E., Fundamentals of Environmental Chemistry, Lewis Publishers, Inc., Boca Raton, 1993.

Sposito,G., Surface Chemistry of Soils, Oxford University Press, New York, 1984.

Stumm,W., and Morgan,J.J., Aquatic Chemistry : An introduction Emphasizing Chemical Equilibria in Natural Waters, 2nd Edition, John Wiley & Sons, New York, 1981.

ES 629 Principles of Environmental Engineering

Overview of environmental systems Water quality standards and water purification processes Nature of sanitary and industrial wastewaters, Primary secondary and advanced treatment methodologies and water reclamation. Air quality standards, classification of atmospheric pollutants and systems for control of air pollution from industries. Noise Pollution and Control. Principles of solid and hazardous waste treatment Potentials for resource and energy recovery

Texts/References

H.S. Peavy,D.R.Rowe, G.Tchobanoglous: Environmental Engineering, McGraw-Hill, 1985.

M.L.Davis and D.A. Cornwell: Introduction to Environmental Engineering, McGraw Hill, 1991.

ME 613 Finite Element and Boundary Element Methods

Introduction, Finite element formulation-variational method, method of weighted residuals, etc. Linear elastic stress analysis-2D, 3D and axisymmetric problems. Analysis of structural vibration, stability, heat conduction, fluid flow, etc. Boundary element formulation for heat conduction and 2D stress analysis. Case studies.

Texts/References

O.C Zienkiewicz, The Finite Element Method, 3rd Edition, Tata McGraw-Hill, 1983.

C.S. Desai and J.F. Abel, Introduction to Finite Element Method, Affiliated East-West Press, 1977.

R.D. Cook, Concepts and Application of Finite Element Analysis, John Wiley , 2nd Edition,1981.

C.A. Brebbia and S. Walker, Boundary Element Techniques in Engineering, Newness Butterworths, 1980.

P.K. Banerjee and R. Butterfield, Boundary Element Method in Engineering Science, McGraw-Hill, 1981.

CE 620 Finite Element Methods

Principles of discretisation; Element stiffness mass formulation based on direct, variational and weighted residual techniques and displacements, hybrid stress and mixed approaches, shape functions and numerical integrations, convergence, Displacement formulations for rectangular, triangular and isoparametric elements for two dimensional and axisymmetric stress analysis; Thin and Thick plates and shells, Semi-analytical formulations; Three dimensional elements and degenerated forms; Stiffener elements and modifications such as use of different coordinate systems, use of nonconforming modes and penalty functions; Application to layered composite plate/shells, bridge, roof, nuclear and offshore structures; Hybrid stress and mixed formulations for plates.

Texts/References

O.C. Zienkiewicz, The Finite Element Method, Tata McGraw-Hill, New Delhi, 1977.

K. J. Bathe, Finite Element Procedures, Prentice Hall, New York, 1995.

CL 603 Optimization

Introduction to Process Optimization; Formulation of Various Process Optimization Problems and their Classification; Basic Concepts of Optimization-Convex and Concave Functions, Necessary and sufficient conditions for Stationary Points; Optimization of one-dimensional Functions; Unconstrained Multivariable Optimization- Direct Search Methods. Indirect First Order and Second Order Methods; Linear Programming and its Applications; Constrained Multivariable Optimization-Necessary and Sufficient Conditions for Constrained Optimum, Quadratic Programming, Generalized Reduced Gradient Method, Successive Linear and Quadratic Programming; Optimization of Staged and Discrete Processes, Dynamic Programming, Integer and Mixed Integer Programming.

Texts/References

T.F.Edgar and D.M.Himmelblau, Optimization of Chemical Processes, McGraw Hill International Editions, Chemical Engineering Series (1989)

G.S.Beveridge and R.S.Schechter, Optimization Theory and Practice, Mc Graw Hill, New York l970.

G.V.Rekllaitis, A.Ravindran, and K.M.Ragsdell, Engineering Optimization-Methods and Applications, John Wiley, New York (1983)

CL 605 Advance Reaction Engineering

Homogeneous reactor design and analysis-I: Ideal reactors, Review of isothermal design for batch, semi-batch and flow reactors, Multiple reactions and reaction networks: Yield-selectivity concepts, Wei-Prater analysis for first order networks, reaction networks of general order, Reactor energy balance and its applications to reactor design and analysis. Homogeneous reactor design and analysis-II: Non-ideal reactors- Review of the basic concepts of residence time distributions, single parameter models for real reactor behavior, Macromixing and micromixing, segregated flow model and Zweitering`s analysis of maximum mixedness, IEM and other models for micromixing. Heterogeneous reactors-I: Gas-solid systems- Review of kinetics of gas-solid catalytic reactions with and without diffusion limitations, Reactor design for fixed and fluidized bed reactors, Selected case studies, Non-catalytic gas-solid reactions: review of kinetics; reactor design case studies. Heterogeneous reactors-II: Gas-liquid systems- Basic theories of mass transfer with chemical reaction model systems and model reactors, Reactor design for mechanically agitated and bubble column reactors. Selected case studies.

Texts/References

Froment, F.G. and Bischoff, K.B., Chemical Reactor Analysis and Design,Wiley, 1990.

Rawlings, J.B. and Ekerdt, J.G., Chemical Reactor Analysis and Design Fundamentals, Nob Hill, 2002.

Carberry, J.J., Chemical and Catalytic Reaction Engineering, McGraw Hill, 1976.

Levenspiel, O., Chemical Reaction Engineering, Third edition, Wiley, 1999. Smith, J.M., Chemical Engineering Kinetics, McGraw Hill, 1981. Doraiswamy,

L.K. and Sharma, M.M., Heterogeneous Reactions, Vol. I and II, Wiley,1984. Danckwerts, P.V., Gas-Liquid Reactions, McGraw Hill, 1970.

CL 712 Process Data Analysis and Design of Experiments

This course will deal with statistical analysis of engineering process data and the design of experiments. Specifically, this course will be concerned with building empirical models (linear as well as nonlinear models) from given data, analyzing the developed models for adequacy, and refining the model if required. Data analysis methods based on covariance structures of the variables will also be discussed. Further, generation of data in an optimal sense by using designed experiments will also be covered. Techniques for finding new operating regions for improved process performance will be discussed. Throughout the course, the main ideas will be illustrated by examples based on experimental or industrial data. The following topics will be covered: Basic Statistics: Confidence intervals; Hypothesis testing; Estimators and their properties Linear and Nonlinear Regression: Maximum-Likelihood estimation; Confidence intervals in linear regression; Hidden extrapolation and multicollinearity in multiple linear regression; Statistical inference in nonlinear regression; Bootstrapping in nonlinear regression Model Adequacy Analysis: Residual analysis: Lack of fit test; Analysis of variance Other Topics in Regression: Transformation and weighting to correct model inadequacies; Variable selection and model building; Generalized linear models; Non-parametric regression techniques Classification and regression trees. Methods based on covariance structures Principal components analysis; Canonical correlation analysis Design of Experiments: Design and analysis of single factor experiments; Experiments to compare k treatment means; 2 level factorial designs for design of experiments with several factors; Analysis of variance in factorial designs; Calculation of effects and relation to regression Blocking 2 level fractional factorial designs with several factors Generators, defining relations, aliasing, design resolution, projection, and fold-over designs in fractional factorial designs Response Surface Methodologies Direction of steepest ascent; Rotatable second order designs

Texts/References

Douglas C. Montgomery, G. C. Runger, Applied Statistics and Probability for Engineers, John Wiley & Sons, 2003.

Douglas C. Montgomery, E. A. Peck, and G. G. Vining, Introduction to Linear Regression Analysis, John Wiley & Sons, 2001.

Norman R. Draper, and Harry Smith, Applied Regression Analysis, John Wiley & Sons, 2003.

Douglas C. Montgomery, Design and Analysis of Experiments John Wiley & Sons, 2001.

George E. P. Box, W. G. Hunter, and J. S. Hunter, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building, John Wiley & Sons, 1978.

David M. Himmelblau, Process Analysis by Statistical Methods, John Wiley & Sons, 1970.

Richard A. Johnson, and Dean W. Wichern, Applied Multivariate Statistical Analysis, Prentice Hall of India Private Limited, New Delhi, 1992.

Douglas M. Bates, and Donald G. Watts, Nonlinear Regression Analysis and its Applications, John Wiley & Sons, New York, 1998.