M.Tech. Ist Semester (Applied Mechanics)

AM-901 APPLIED ELASTICITY

4(L) - 0(T) - 0(P) - 4(Cr)

Analysis of Stress: Concept of Stress, Stress Components, Equilibrium Equations, Stress on a General Plane (Direction Cosines, Axis Transformation, Stress on Oblique Plane through a point, Stress Transformation), Principal Stresses, Stress Invariants, Deviatoric Stresses, Octahedral Stresses, Plane Stress, Stress Boundary Condition Problem.

Analysis of Strain: Deformations (Lagrangian Description, Eulerian Description), Concept of Strain, Strain Components (Geometrical Interpretation), Compatibility Equations, Strain transformation, Principal Strains, Strain Invariants, Deviatoric Strains, Octahedral Strains, Plane Strain, Strain Rates.

Stress-Strain Relations: Introduction, One-Dimensional Stress-Strain Relations (Idealized Time-independent and Time –dependent stress-strain laws), Linear Elasticity (Generalized Hooke's Law), Stress-Strain Relationships for Isotropic and Anisotropic Materials (Plane stress and Plane Strain).

Basic Equations of Elasticity for Solids: Introduction, Stresses in Terms of displacements, Equilibrium Equations in terms of displacements, Compatibility equations in Terms of Stresses, Special cases of Elasticity equations (Plane Stress, Plane strain, Polar Co-ordinates), Principle of Superposition, Uniqueness of Solution, Principle of virtual work, Potential and Complementary energy, Variational Principles, St. Venant's Principle, Methods of analysis for Elastic Solutions, Elastic solutions by Displacement and stress Functions, Airy's Stress Function (Plane stress, Plane strain, Polar Co-ordinates).

Torsion: Introduction, Circular shaft, Torsion of non-circular cross-section, St. Venant's theory, Warping function, Prandtl's stress function, Shafts of other cross-sections, Torsion of bars with thin walled sections.

Plasticity: Introduction, Basic Concepts, Yield Criteria (Tresca, Von-Mises, Mohr Coloumb, Drucker-Prager), Yield Surface, equivalent stress and equivalent strain, Plastic work, Flow Rule-Plastic Potential, Elastic-Plastic and plastic stress-strain relations, Plastic Flow of anisotropic materials.

Viscoelasticity and Viscoplasticity: Introduction, Viscoelastic models (Maxwell, Kelvin-Voigt, Generalized Maxwell and Kelvin models), Viscoelastic stress-strain relationships, Viscoplasticity.

References:

1. "Mathematical Theory of Elasticity" by I. S. Sokolnikoff.

2. "Advanced Mechanics of Materials" by Boresi.

3. "Theoretical Elasticity" by A. E. Green and W. Zerna.

4. "Theory of Elasticity" by Timoshienko.

5. "Advanced Strength and Applied Elasticity" by A. C. Ugural and S. K. Fenster.

6. "Applied Elasticity" by R.T.Fenner.

7. "Advanced Strength of Materials" by L. S. Srinath.

AM-902 APPLIED COMPUTATIONAL METHODS

3(L) - 0(T) - 2(P) - 4(Cr)

Introduction: Motivation, Mathematical modeling, Errors in numerical methods, Convergence, Conditioning and stability.

Nonlinear Equations: Motivation, Open and braketing method, Bisection, Fixed point, Newton's method, Secant and False position method, Rate of convergence, Merits and demerits of methods.

Simultaneous Linear Equations: Motivation, Gauss elimination, Pivoting, Factoring, Solution accuracy, Iterative methods, Jacobi method, Gauss-Siedel method, Relaxation method.

Interpolation and Curve Fitting: Motivation, Polynomial forms, Linear interpolation, Lagrangean interpolation, Newton interpolation, Spline interpolation, Chebyshev interpolation, Regression analysis, Fitting linear equations, Least-square method, Fitting transcendental equations, Polynomial functions, Multiple linear regression.

Simultaneous Non-Linear Equations: Motivation, Successive substitution method, Newton's method.

Numerical Integration: Motivation, Newton-Kotes method, Trapezoidal rule, Simpson's rule, Rhomberg integration, Gauss Quadrature.

Initial Value Problem: Motivation, Euler's method, Modified Euler method, Runge-Kutta methods, Adaptive integrations and multistep methods.

Boundary-value and Eigen-value Problem: Motivation, Shooting method, Finite difference method, Finite volume method, Polynomial method, Power method, Elliptic, Parabolic and Hyperbolic Partial Differential Equations.

References

1. "Applied Numerical Analysis", C.F. Gerald and P.O. Wheatley, 5th edition, Addison-Wesley, 1998.

2. "Numerical Mathematics & Computing", W. Cheney and D. Kincaid, 5th edition, Brooks/Cole, 2004.

3. "Applied Partial Differential Equations", Paul DuChateau and David Zachmann.

4. "Partial Differential Equations for Scientists and Engineers", Stanley J. Farlow.

5. "Numerical Methods for Partial Differential Equations", William F. Ames.

6. "Numerical Methods for Elliptic and Parabolic Partial Differential Equations**",** John R Levison, Peter Knabner, Lutz Angermann .

AM-903 EXPERIMENTAL METHODS AND DESIGN

3(L) - 0(T) - 2(P) - 4(Cr)

Part-A: Design of Experiments

Introduction: Strategy of Experimentation, Some Typical Applications of Experimental Design, Basic Principles, Guidelines for Designing Experiments, A Brief History of Statistical Design, Using Statistical Techniques in Experimentation.

Factorial Designs: Basic Definitions and Principles, The Advantage of Factorials, The Two-Factor Factorial Design, The General Factorial Design, Fitting Response Curves and Surfaces, Blocking in a Factorial Design, Unbalanced Data in a Factorial Design, The Analysis of Covariance, Repeated Measures. Method of rejecting a reading, Methods for increasing accuracy of experiments, propagation of errors in experiments. Error & Uncertainty analysis.

Part-B: Measurements in Fluid Mechanics

Pressure Measurements: High and low pressures, dynamical characteristics of pressure measuring devices. Pressure transducers, Multi-hole pressure probes, Ultra low and very high pressure measurement.

Velocity Measurements: Velocity and Mach number from pressure measurement, Vortex-shedding technique, Hot-wire anemometry, Laser Doppler anemometry, Particle image velocimetry.

Discharge Measurements: types of flow-rate meters, rotameter, turbine flowmeter, magnetic flowmeter, coriolis flowmeter.

Miscellaneous Measurements: Temperature Measurement, Wall shear measurement.

Flow Visualization Techniques: Various flow-visualization techniques. Study of different types of wind tunnels, their design criteria, testing procedure, wind tunnel boundary corrections, use of wind tunnel data. Testing, calibration & standardization of instruments, national and international standards like NABL, ISO.

Part-C: Measurements in Solid Mechanics

Introduction: Overview of elementary elasticity theories, Different strain measurement techniques in solid mechanics.

Electrical Resistance Strain Gauge (ERSG): Introduction, Strain sensitivity of metallic alloys, Working mechanism of ERSGs, Gage sensitivity and gage factor, Application methodologies of ERSGs.

Semiconductor Strain Gage (SCSG): Piezoresistive property and semiconductor materials, Making of SCSGs, Performance characteristics of SCSGs.

Strain Gauge Circuits: Introduction, Potentiometer circuit, Wheatstone Bridge Circuit, Constant current circuit vs constant voltage circuit, Calibration of strain gage circuits, Effects of lead wires, switches, slip rings, Transducer applications.

Recording Instruments and Analysis of Strain gage Data: Type of recording instruments, Strain Rosettes- three-element and delta rosette, Corrections, Stress gage.

Optical Methods of Stress Analysis: Introduction, Moire methods, Basics of photoelasticity.

References:

1. "Design & Analysis of Experiments", D.C. Montgomery, Wiley, 7th ed., 2009.
2. "Statistics for Experimenters: Design, Innovation & Discovery", E. P. Box, W.G. Hunter, J.S. Hunter, Wiley-Interscience, 2nd ed. 2005.
3. "Design of experiments for Engineers & Scientists", J. Antony, Butterworth-Heinemann, 1st ed., 2003.
4. "Instrumentation, Measurements & Experiments Fluids", E. Rathakrishnan, CRC Press, NY, 2007.
5. "Experimental Methods for Engineers", J.P. Holman, McGraw-Hill Inc., NY, 2001.
6. "Measurement Systems: Applications & Design", E.O. Doebelin, McGraw-Hill Inc.
7. "Mechanical Measurement" (5th ed.), T.G. Beckwith, Pearson Education, New Delhi, 2001.
8. "Temperature Measurement" (2nd ed.), L. Michalski, John Wiley & Sons Ltd., NY, 2001.
9. "Mechanical Measurements", D.S. Kumar, Metropolitan Book Agency, New Delhi.
10. "Pressure-Probe Methods for Determining Wind Speed and Flow Direction", D.W. Bryer and R.C. Pankhurst, Her Majesty's Stationery Office, London, 1971.
11. "Low-Speed Wind Tunnel Testing", A. Pope and J.J. Harper, John Wiley & Sons Inc., NY, 1966.
12. "Experimental Stress Analysis", James W. Dally and William F. Riley, McGraw-Hill Book Company.

List of Experiments:

Experiments are to be conducted at Solid Mechanics & Fluid Mechanics Labs. with available measurement facilities using statistical and regression analysis of practical data obtained.

AM-904 DYNAMICS OF STRUCTURE

4(L) - 0(T) - 0(P) - 4(Cr)

Overview: Objectives, Types of Loadings, Essential Characteristics of Dynamic Problems, Methods of Discretization, Formulation of the Equation of Motion: Dynamic Equilibrium, Principle of Virtual Displacements, Hamilton's Principle, Lagrange's Equation, Element Energy Functions: Axial, Torque, Beam bending, Membrane, Thin & Thick plates, 3-D Solid, Axisymmetric Solid.

Single-Degree-of–Freedom Systems: Analysis of Free and Forced Vibrations, Response to Harmonic, Periodic & Impulsive Loadings, Vibration Isolation, Complex-Stiffness Damping, Approximate Analysis of Impulsive Load Response, Response to General Dynamic Loading (Superposition methods, Step-by step methods), Generalized Single Degree of Freedom Systems.

Multi-Degree-of-Freedom Systems: Formulation of MDOF Equation of Motion, Evaluation of Structural Property Matrices, Analysis of Dynamic Response- Superposition method, Vibration Analysis by Matrix Iteration, Step-by Step methods, Variational Formulations, Guyan Reduction technique, Holzers Method, Stodala Method, Reilay Methods.

Vibration of Continious Systems

Random Vibration: Probability Theory, Random Processes, Stochastic Response of SDOF & MDOF Systems.

References

1. Dynamics of Structures: Clough and Penzien
2. Structural Dynamics: Mukhopadhyay
3. Elements of Vibration Analysis: Meirovitch
4. Mechanical Vibrations: Grain and Rixen
5. Structural Dynamics (Theory & Computation): Mario Paz

AM-905 ADVANCED FLUID MECHANICS

4(L) - 0(T) - 0(P) - 4(Cr)

Basic Conservation & Governing Laws: Statistical & continuum methods, Eulerian & Lagrangian coordinates, material derivatives, control volumes, Reynolds' transport theorem (RTT), conservation of mass, momentum and energy, constitutive equations, Navier-Stokes equations-differential & intergral approach, energy equations, governing equations for Newtonian fluids, boundary conditions.

Potential Flows: Stokes stream functions, solution of potential equation, flow in a sector, flow around a sharp edge, flow near a blunt nose force and moment on a circular cylinder and sphere, conformal transformations, Joukowski transformations, Elements of airfoil and wing theory.

Viscous Incompressible Flows: Exact solutions for Couette flow, Poiseuille flow, flow between rotating cylinders, Stokes' first problem, Stokes' second problem, pulsating flow between parallel surfaces, stagnation-point flow, flow in convergent and divergent channels, flow over porous wall. Stokes approximation, rotating sphere in a fluid, uniform flow past a sphere and cylinder, Ossen's approximation, Hele-Shaw flow.

Introduction to Boundary Layer: Review of boundary layers: laminar and turbulent boundary layers; transition; separation.

Introduction to turbulence: Transition of flows, Origin of turbulence- its consequences, Physics of turbulent motion- concept of Reynolds stress, mean flow equations, Prandtl mixing length theory, Reynolds Equation. Characteristic scales of turbulence and order of magnitude- Kolmogorov scales. Isotopic and homogeneous turbulence. Energy Equation-correlation and spectrum.

Introduction to Compressible Flow: Velocity of sound and its importance, physical difference between incompressible, subsonic and supersonic flows, Mach no. Application to subsonic, transonic and supersonic flow around a two-dimensional aerofoil.

References

1. "Fundamental Mechanics of Fluids", I. G. Currie.
2. "Foundations of Fluid Mechanics", S.W. Yuan, Prentice-Hall India Pvt. Ltd, New Delhi.
3. "Advanced Fluid Mechanics", K. Muralidhar & G. Biswas, Narosa Publishing, 2005.
4. "Boundary Layer Theory", H. Schlichting, 6th Edition, McGraw-Hill Inc., 1986.
5. "Turbulent Flow", R. J. Garde, 2nd Edition, New Age International Publishers.
6. "Modern Compressible Flow with Historical Perspective", John D. Anderson, McGraw Hill.

7. "Fundamentals of Aerodynamics" (2nd ed), J. D. Anderson, McGraw Hill.
8. "Fundamentals of Fluid Mechanics", B.R. Munson, D.F. Young & T.H. Okiishi, 2nd Ed., John Wiley.
9. "Introduction to Fluid Mechanics", R.W. Fox & A.T. McDonald, 5th Edition, John Wiley, 2001.
10. "Viscous Fluid Flow", F. M. White, 2nd Edition, McGraw-Hill, 1991.

AM-906 DESIGN OF INDUSTRIAL STRUCTURES

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction: Line and surface structures; Internal/induced forces- Axial/Membrane, Bending/Flexure, Shear and Torsion; Thin and thick structures, Sandwich constructions.

Theory of Plates: Governing differential equation and boundary conditions, Membrane & Bending actions; Rectangular Plates- various loading and edge conditions; Navier's solution; Levy's solution; Circular Plates- Governing equations in polar coordinates, various loading and edge conditions.

Theory of Shells: Introduction- importance and applications of shell structures; Bending Theory of Shells- Governing equations and special cases, Flugge and Donnel theories; Membrane Theory of Shells**-** Governing equations, Shells of revolution, Cylindrical, Spherical and Conical shells, Axisymmetric and Asymmetric loading; Combination of Bending and Membrane Actions.

Design of Pressure Vessels and Piping: Design of pressure vessels- Introduction, Design of different kind of vessels, Openings and nozzles; Design of pipings- Introduction, Design of different piping systems, Branch connections, Pipe flanges.

Design of Shells of General Shape: Hyperbolic Paraboloid Shell, Folded plates, Bunkers, Silos, Chimneys, Towers, Cooling towers.

References

1. S. P. Timoshenko and W .Krieger, 'Theory of Plates and Shells'.

2. Donnell, 'Beams, Plates and Shells'.

3. Jack R. Vinson, 'Plate and Panel Structures of Isotropic, Composite and Piezoelectric Materials Including Sandwich Construction'.

4. N. E. Shanmugam and C. M. Wang (Eds), 'Analysis and Design of Plated Structures'.

5. Turner, 'Plates and Shells'.

6. J. Ramachandran, 'Thin Shells- Theory and Problems'.

7. M. L. Gambhir, 'Stability Analysis and Design of Structures'.

AM-907 MECHANICS OF FRP COMPOSITE MATERIALS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction: Classification and characteristics of composites, Conventional vs. Composite materials, Advantages and limitations, Salient applications in various fields, Fabrication technologies.

Micromechanics: Determining fibre volume fraction, Properties of matrix and reinforcement materials, micro-mechanic relations, determination of strength and stiffness, Environmental effects, Hygro-thermal behavior.

Macro-Mechanics: Basic stress-strain relationships for anisotropic materials, engineering constants for orthotropic materials, stress-strain relations for a lamina of arbitrary orientation, effective moduli, invariant properties of an orthotropic lamina, Strength of an orthotropic lamina. special cases of laminate stiffness, laminate strength analysis, failure theories for lamina, concept of inter-laminar stresses and delamination.

Composite Structures: Classical lamination theory, shear deformation theories, Governing differential equations for Bending, Buckling and Vibration of Laminated Plates.

Characterization & Testing: Characterization of fiber & matrix, Determination of Tensile, Compressive & shear strength .

Design of composite structure

References

1. R. M. Jones,- Mechanics of Composite Material

2. B. D. Agrawal and L.J. Brountman, Analysis and Performance of Fiber Composite,

3. Stephen W.Tsai and H. Thomas Hahn, 'Introduction to Composite Material",

4. J. R. Vinson and T.W. Chou, "Composite Materials and their use in Structures",

5. J. N. Reddy and A.V. Krishna Moorty, "Composite Structures, Testing, Analysis and Design

AM-908 FINITE ELEMENT METHODS

3(L) - 0(T) - 2(P) - 4(Cr)

Introduction: Course objectives, Basic steps in the Finite-Element formulation, Elemental Equations, Assembly, Imposition of Boundary Conditions, Shape Functions, Sub parametric, Super parametric & Isoparametric elements, Convergence Criteria, h and p Approximations.

Finite Element Formulation: Variational methods, Ritz Method, Method of Weighted Residuals, Galerkin method, Strong & Weak formulation and Time Dependent Problems.

Finite Element Analysis of One-Dimensional Problems: Introductory Comments, one-dimensional second order equations, one dimensional fourth order equations, Coordinate transformation & Jacobian, Numerical Integration, Gauss Elimination.

Finite-Element Analysis of Two-Dimensional Problems: Second-order equation involving a scalar valued function, Two-dimensional finite-elements and interpolation functions, second-order multivariable equations, Plane elasticity problems.

Advanced Topics : Error & Error estimation , Conforming & Non conforming Elements, Patch test, Eigenvalue Problems, Nonlinear problems, 3-D Problems.

Lab Experiments: Based on ANSYS, Nastron.

References

1. "An introduction to FEM" by J. N. Reddy.

2. "Finite Elements and Approximations" by O.C. Zienkeiwicz and Margan.

3. "The Finite Element Method Vol.-I" by O.C. Zienkiwicz and R. L. Taylor.

4. "The Finite Element Method Vol-II" by O.C. Zienkiwicz and R.L. Taylor.

5. "Finite Element Methods in Engineering" S. S.Rao.

AM-996 Seminar/Minor Project

0(L) - 0(T) - 2(P) - 2(Cr)

Study of old MTech thesis of the department, Research paper presentation from the pool of papers contributed by faculties of the department/ his own choice approved by the department, To learn to solve the problems using available software/packages in the department, Writing of paper on a topic and its Poster presentation at the end.

ELECTIVES

AM-915 MECHANICAL BEHAVIOUR OF MATERIALS

4(L) - 0(T) - 0(P) - 4(Cr)

Mechanical behaviour of engineering materials: Deformation in Materials.

Mechanism of Elastic, Plastic, Anelastic and Visco-elastic deformation and their Characteristic;

Creep: Mechanisms, creep laws, Analysis and Applications in Design.

Fractures: Types and their characteristics. Nucleation of cracks and their growth, Variables influencing the fracture, Brittle fracture theories, Cleavage fracture, Methods to improve fracture strength, Cracks as Stress Raisers, Effects of Cracks on Strength, Effects of Cracks on Brittle versus Ductile Behaviour.

Fatigue: Sources of cyclic loading, defining cyclic loading, Variable Amplitude Loading, The Palmgren - Miner Rule, Cycle Counting For irregular Histories, S-N Curves, Life Estimates, Mechanisms of Fracture and crack growth, Fatigue Crack Growth, Trends in FCG behaviour, Effect of R and stress Range, Design Considerations, Elastic crack tip stress field,

Fracture Mechanics: Stress intensity factor K, Application of K to Design & Analysis, Energy principles and criteria for crack growth, Strain Energy Release Rate, G, Trends in K_{IC} with material, Effects of Temperature and loading rate, Micro-structural Influences on $K_{IC,}$ Plane strain and plane stress fracture toughness, crack tip plastic zones, Plastic zone size and Plasticity limitation on LEFM for FCG, The J integral - Extension of Fracture Mechanics beyond linear Elasticity CTOD, Crack opening displacement criteria, Fatigue crack propagation under constant and variable amplitude loading, Crack closure, Effective stress intensity range, Concept of safe life, Fail safe and damage tolerance, Linear damage accumulation theory, Strain Based Approach, Strain versus life curves, Physical nature of Fatigue Damage Failure modes,

Mechanical Testing of Materials: Tensile, Compression, Shear, Torsion, Hardness, Impact, Creep, Fatigue, Fracture toughness tests, effect of thickness on Fracture Behaviour, Tests for formability: Test apparatus, test specimen

Measurement: of stress and strain: Load cells, Optical, electrical and electronic strain measuring devices, Computer controlled Servohydraulic test machines, Brittle lacquers. Measurement of residual stress

Non-destructive testing techniques: Ultrasonic testing, Radiography, Acoustic emission, eddy current testing, Liquid penetrant testing, Magnetic method of crack detection, Macrofractography and microfractography techniques

Term Paper: On application/recent advances based on literature survey and/or lab/industry visit(s).

References

1. Mechanical Behaviour of Material, Englewood Cliffs, Prentice Hall, New Jersey, 1993
2. Fracture Mechanics by Prashant Kumar
3. Mechanical Behaviour of Materials, Keith Bowman
4. Mechanical Behaviour of Material, Norman E. Dowling, Prentice Hall.
5. Mechanical Behaviour of Material, Courtney Browne, McGraw Hill, 1990
6. Mechanical Behaviour of Material, F. McClintock, A.S. Argon, Reading Mass, Addison-Wesley Pub Co, 1966
7. Introduction to Fracture Mechanics - Kare Hellan, McGraw
8. Engineering Fracture Mechanics by David Broek, Martinues Nijhoff Publishers Ltd.
9. Introduction to Fracture Mechanics David Brookes,
10. Zbigniew D.Jastrzebski, "The Nature and Properties of Engineering Materials, 3rd ed. John Wiley & Sons".
11. A. H. Cottrell, "Dislocation and Plastic Materials".
12. J. P. Hirth and J. Lothe, "Theory of Dislocations, McGraw Hill".

AM-956 CARBON NANOTUBE AND CARBON NANOSTRUCTURE

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction, carbon molecule, carbon small clusters, carbon big clusters, fullerenes, discovery of $C_{60,}$ synthesis of C_{60}, properties of C_{60}, other buckeyballs, CNT, structure, fabrication methods, defects, chemistry of CNT, electrical properties, vibrational properties, chemical properties, mechanical properties, physical properties, optical properties, applications of CNT, modeling of CNT, CNT reinforced composites, Applications of CNTs, other nanostructures.

Term Paper: On application/recent advances based on literature survey and/or lab/industry visit(s)

AM-958 COMPUTATIONAL MATERIALS SCIENCE

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction and Fundamentals: Introduction to various regimes, multiscale modelling & simulation of materials, System size vs computation time, Parallel processing

Ab Initio Methods Density functional theory, Quantum mechanics, Schrodinger Wave Equation, Many particle system, Car Parrinello method, Born Openheimer approximation, Hohenberg-Kohn Theorem, Kohn Sham Formulation, Local Density Approximation, Bloch's theorem, Pseudo Potential, Energy minimisation techniques, Examples of crystals and non-crystals

Atomistic Level Modelling, Review of thermodynamic laws, Micro & Macro state, Ergodic System, Partition function, Statistical Mechanics, thermodynamic ensembles, **Monte Carlo Simulation**- Markov Process, Algorithm and application of MC simulation (percolation problem etc). **Molecular Dynamics-** Force fields, MD algorithm, accelerating MD, Verlet algo, Leap frog method, Velocity verlet method, Gear Algo, Particle Mesh method, Multipole method, Fast multipole method

Lattice Mesoscale methods: lattice gas automata, Lattice director model

Coarse graining: Particle based models-Lattice gas model, Connolly Williams Approximation, Spatial models, Dynamic (temporal) models, Application to polymer and polar materials.

Grain continuum modelling, Computational micro-mechanics, Multiscale coupling

Term Paper on application of Multiscale Modelling to

Composite damage

Dislocation behaviour

Phase field modelling

Modelling of grain growth and microstructure in polycrystalline materials

Modelling of structural materials

And other recent advances based on literature survey

Text Books

1. Introduction to Materials Modelling, Ed Zoe H. Barber, Maney Publishing, 2005

2. Computational Material Science From Ab Initio to Monte Carlo Methods, K. Ohno, K.Esfarjani, Y. Kawazoe, Springer, 1999

References

1. Multiscale Materials Modelling: Fundamentals and Applications, Ed Z Xiao Guo, Woodhead Publishing Limited, Cambridge, 2007.

2. Computational Meso-mechanics of Composites, Leon Mishnaevsky, Jr., John Wiley & Sons, 2007

3. Multi-scale modelling of Composite Material Systems, C. Soutis & P.W.R. Beaumont Woodhead Publishing Ltd., 2005

4. Continuum Scale Simulation of Engineering Materials-Fundamentals, Microstructures, Process Applications, Dierk Rabbe, Barlat,Wiley, 2004

5. Annual Review of Materials Research on Computational Materials Research, Vol 32, 2002

6. Understanding Molecular Simulation- from Algorithm to Application, Frenkel Daan, Smit Berend. Academic Press., 1996

7. Notes of Workshop on Computational Materials Science, at Indian Institute of Sciences, Bangalore, 06 - 08 Mar 2009.

8. Computational Material Science, Dierk Raabe, Wiley-VCH Verlag GmbH, 1998

9. Multiscale Modelling & Simulation, Attringer & Coumoutsakos, Springer

10. Computational Materials Design, Tetsuya, Springer

11. Combinatorial Material Science, Balaji narasimhan, Surya K Mallaprajada, wiley, 2007

12. Materials Informatics, Data-Driven Discovery in Material Sc, Krishana Rajan, Wiley, 2007

AM-959 DAMAGE MODELLING OF COMPOSITE MATERIALS

4(L) - 0(T) - 0(P) - 4(Cr)

Part (I): Introduction to Damage Modelling: Continuum Damage Mechanics, Thermodynamics of damage, Measurement of damage, isotropic damage, Kinematic

description of damage, Anisotropic damage, Effect of isotropic damage evolution on (visco) plasticity, Coupled damage plasticity.

Part (II): Damage Modelling of Composites: Molecular modelling of composite matrix properties, strength and stiffness modelling, interfacial damage modelling, cracking modelling, fracture modelling, wear modelling, impact damage modelling, fatigue damage modelling, creep, visco-eleastic and dynamic behaviour.

References

1. Modeling of material damage and failure of structures: theory and applications by J.Skrzypek, A.

Ganczarski.

2. Engineering Damage Mechanics by J.Lemaitre & R.Desmorat.

3. Damage Mechanics by G.Z. Voyiadjis & P.I. Kattan

4. R. M. Jones, Mechanics of Composite Material, McGraw Hill Pub., New York, 1975.

5. J. N. Reddy and A.V. Krishna Moorty, "Composite Structures, Testing, Analysis and Design, Narosa Publishing House, New Delhi, 1992.

6. C. Soutis & P.W.R. Beaumont, Multi-scale modelling of composite material systems: The art of

predictive damage modelling, Woodhead Publishing and Maney Publishing, 2005

AM-960 DEGRADATION OF MATERIALS IN SERVICE

4(L) - 0(T) - 0(P) - 4(Cr)

Corrosion, Oxidation, Radiation, wear and Allied Processes etc.:

Corrosion: Types, Galvanic cell, wet and dry corrosions , Laws of corrosion, Oxidation, Mechanisms, Passivity , Special types of corrosions , Methods of protection against corrosion.

Fundamentals of corrosion, Importance of corrosion, Dry and wet corrosion, Mechanism of corrosion, Electrochemical and thermodynamic principles of corrosion, Electrode potential of metals., Nernest equation, Reference electrodes, EMF and Galvanic series, E-pH diagrams, Kinetics of electrochemical corrosion, Exchange current density, Polarization at electrodes, Laws and rate of corrosion.

Different types of corrosion, Liquid metal corrosion, Molten salt corrosion. High temperature corrosion, Atomospheric corrosion, Intergranulr corrosion, Pitting, Hydrogen embrittlement, Stress corrosion cracking, Cavitation corrosion, Fretting corrosion, crevice corrosion, Selective leaching etc., Oxidation, Pilling-Bedworth ratio, Corrosion in acidic, alkaline and salty environments, Hydrogen attack, Passivity, Corrosion prevention methods viz. design improvements, Inhibitors, Catholic protection, Anodic protection and preventive coatings, Corrosion and oxidation resistant materials, Materials selection for different environments.

Corrosion testing techniques: Electroc-chemical measuresment, Weight change measurements. Corrosion and Oxidation resisting materials.

Radiation damage: Introduction and nature, types of radiation damage in different materials.

Wear and Tribology

Term Paper: On application/recent advances based on literature survey and/or lab/industry visit(s)

References

1. J. C.Scully, "The Fundamentals of Corrosion", Pergamon.

AM-964 ELECTROACOUSTICS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction to Acoustics: Acoustic variables & Basic relations, Plane & Spherical waves, Reflection & Transmission, Radiation & Reception of acoustic waves, Absorption and Attenuation of Sound.

Electro-Mechano-Acoustical Analogy: Introduction, Basic equations and Impedances, Transformer and gyrator, Simple harmonic oscillator, Helmholtz resonator, Loop analysis, Circuit elements, Lagrange equation.

Acoustical Elements: Basic acoustic elements, Specific acoustic impedance, Mechanical impedance, Electrical impedance, Acoustic Radiation impedance, Duct impedance, Equivalent circuit model, Various acoustical examples, frequency and wavelength, dB scale, Sound pressure level.

Basic theory and modelling of microphone: Introduction, Types, Response, Sensitivity, Specifications, Directivity pattern, Microphone array, Microphone equation, Electret condenser microphone (ECM), ECM model for various types of microphone.

Basic theory and modelling of moving coil transducer: Introduction, Types, Reciprocal and anti-reciprocal system, TS parameters, Speaker non-linearities, Equivalent circuit representation, Loudspeaker enclosure, Types of loudspeaker enclosure and corresponding circuits, Total harmonic distortion, Intermodulation distortion, miniature loudspeaker.

Theory and analysis of piezoelectric transducer: Brief introduction to Piezoelectricity, Piezoelectric materials, Piezoelectric devices, Polarization, Equivalent circuit, Piezoelectric accelerometer, Piezoelectric speaker, Piezoelectric microphone.

References

1. L. L. Beranek: Acoustics
2. W. M. Leach: Introduction to Electro acoustics and Amplifier Design
3. H.Kuttruff: Acoustics-An Introduction
4. Kinsler, Frey, Coppens, and Sanders: Fundamentals of Acoustics

AM-966 FUNCTIONALLY GRADED MATERIALS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction: Definition, History of development, Present state of the art, Applications.

Lessons from Nature: Morphological characteristics of biological tissues, A natural optimization process: adaptive modeling with cell-based mechasensor- Bamboo.

Graded Microstructure: Structure, Microstructure, Microstructure characterization, Microstructural analysis, Nonuniform materials, Characteristic dimensions, Spatial variation, Volume fraction, Connectivity, Field parameters.

Characterization of Properties of FGM: Electrical conductivity, Betti number, percolation, Fractal, Quasi-electric field, Dielectric permittivity, Dielectric constant, Capacitance, Ceramic actuator, Piezoelectricity, Thermal conductivity, Thermal diffusivity, Thermal expansion, Thermal stress, Effective thermal conductivity, Apparent thermal diffusivity, Fourier number, Young's modulus, Poisson's ratio, Residual stress, strain hardening, Fracture toughness, Fatifge, Creep, Acoustic emission, Thermal fatigue.

Manufacturing Processes: Introduction, Brief classification of manufacturing processes, Powder metallurgical processes, Deposition and spray processes, Reaction forming processes, Other novel/recent processes.

Modeling, Analysis and Design: Introduction, Macrostructural thermomechanical properties, Effective material properties for ceramic-metal FGMs, Local fields in FGMs, Modeling elasto-plastic deformations of FGMs, Modeling for thermal loading, Mathematical modeling of axi-symmetric FGM, Modeling and analysis of beams and plates of FGMs.

References

1. 'Functionally Graded Materials- Design, Processing and Applications', Miyamoto, Y.; Kaysser, W.A.; Rabin, B.H.; Kawasaki, A.; Ford, R.G. (Eds.).

2. 'Advanced Materials and Structures for Extreme Operating Conditions', Jacek J. Skrzypek, Artur W. Ganczarski, Franco Rustichelli and Halina Egner.

3. 'Functionally Graded Materials (1996)', I. Shiota and Y. Miyamoto (Eds).

4. 'Functionally Graded Materials- Nonlinear Analysis of Plates and Shells', Hui-Shen Shen.

AM-969 MEMS & BIO-MEMS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction: MEMS, microsystem, sensor, actuator, history, market, applications etc.

Review of essential mechanical, electrical concepts: Mechanical: Stress, strain, beam, cantilever, plates, bending, thermal stress, torsion of beam, fracture, vibration etc.

Electrical: Conductor, insulator, semiconductor

Scaling laws in miniaturization: Scaling in geometry, force, electricity, fluid, heat transfer, etc.

Material for MEMS: Review of crystal structure, miller indices, material for MEMS, substrate, device, packaging, silicon, silicon compound, gallium arsenide, piezoelectric martial, quartz, polymer, biomaterials and biocompatibility issues etc.

Micro total analysis system (TAS): Fluid control components,-TAS: sample handling, -TAS: separation components, -TAS: detection, cell handling and characterization systems, systems for biotechnology and PCR, polynucleotide arrays and genetic screening,

Sensing and actuation: Electrostatic sensing and actuation, thermal sensing and actuation, piezoelectric and piezoresistive sensing and actuation, magnetic sensing and actuation, miniature biosensors, biosensors arrays and implantable devices, neural interfaces, microsurgical tools, micro needles, and drug delivery, Microsystems for tissue engineering, tissue scaffolds, optical biosensors, etc.

Fabrication of MEMS: Bulk micromachining, surface micromachining, lithography, LIGA, SLIGA, etc

MEMS packaging: MEMS metrology, Overview of packaging of microelectronics, packaging design, technique, material, etc

MEMS Design and Software: Design methodologies for MEMS, study of following softwares based on availability: Ansys multiphysics, COMSOL multiphysics, MatLab, Intellisuite, AutoCAD, SolidWorks, Spice, Ledit etc.

Case studies: Detailed case studies of following MEMS devices: Piezoresistive pressure sensor, Capacitive accelerometer.

Homework Design, analysis, layout, and simulation of MEMS devices

Project Small research project summarized in a four-page write-up (abstract style). One presentation based on the research work of any paper of your choice in the field of MEMS.

Books

1. Foundations of MEMS, Chang Liu, Pearson Education International, 2006
2. MEMS and MICROSYSTEM Design and Manufacture, Tai-Ran Hsu, Tata Mcgraw-Hill Publishing company Ltd., New Delhi, 2002
3. Microsystem Design, S. D. Senturia, Kluwer Academic Publishers, 2001
4. Fundamentals of Microfabrication, Marc Madou, CRC Press, NY, 1997.
5. A. Manz and H. Becker, Eds. Microsystem Technology in Chemistry and Life Sciences Springer-Verlag, New York, 1999. ISBN: 3-540-65555-7
6. Max.I..Madou, "Fundamentals of Micro Fabrication, the Science of Miniaturization", Nanogen corporation, USA, CRC press, March 2002.

AM-971 NANO-MATERIALS AND MECHANICS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction to Nanotechnology: Nano technology, Nano science, MEMS, CNT, Fullerene, Nano machines, Semiconductor technology etc.

Solid State Physics: Introduction, Structure (Physics of solid state), FCC nanoparticle, Semiconductor structures Lattice Vibration, Energy Band, Reciprocal space, Fermi surfaces, Localized Particles, mobility, exciton, etc.

Methods of Measuring Properties: Measurement Methods, Structure – Atomic, Crystallography, Particle Size, Mass spectroscopy, LEED, RHEED, Surface Structures, Microscopy – TEM, SEM, FIM, AFM etc.

Properties of Nanoparticles: Properties of Nano-Particles, Metal Nano-Clusters, Semi conducting Nano-Particles, Semi conducting Nano-Particles, Rare Gas & Molecular Clusters, Methods of Synthesis.

Carbon Nano-Structures: Carbon Nano-Structures, Carbon-molecule, Carbon Clusters, C_{60}, $C_{20}H_{20}$, C_8H_8, CNT, Applications.

Bulk Nano-Structured Materials: Solid disordered nanostructures: Synthesis, Failure, Mechanical properties, Multilayers, Electrical properties, other properties, Composite glasses, Porous silicon, Nanostructured Crystals: Natural crystals, Array in zeolites, Metal nanoparticles, Photonic crystals.

Nanostructured Ferromagnetism: Basic, Para, Ferro, Ferri, Antiferro-magnetism, Effect of bilk nanostructuring on magnetic properties, Dynamics of Nanomagnets, Nanopore containment, Nanocarbon ferromagnets, Giant and colossal magnetoresistance, Ferrofluids.

Quantum nanostructure, Self Assembly and deposition: Quantum Wells, Wires and Dots, preparation, Size effect, Single electron tunneling, Applications etc.Process, Monolayer, Multiplayer, LB film deposition, CVD, PVD, Sputtering etc.

Polymers and Biological nanomaterials: Forming and characterization of polymer, Nanocrystals, Conductive and Block polymers, Supramolecular structures, Biological building blocks, Nucleic acids, Biological nanostructures, etc.

MEMS and NEMS: Brief introduction to history, Microsystem, Sensor, Actuator, History, Market, Applications, Actuation and Sensing, Fabrication, Nano-electro mechanical system, Fabrication, Nano-devices and Nano-machines, Molecular & Super- Molecular Switches

Homework: Report on History & Current status of Nanotechnology and nanomachines etc.

Project: Small research project summarized in a four-page write-up on the nano-fabrication, nanodevice(abstract style). One presentation based on the research work of any paper of your choice in the field of Nanoscience and nanotechnology, Visits to various labs.

References

1. Introduction to Nanotechnology, C. P. Poole Jr. and F. J. Owens, Wiley Inter Science.
2. There's Plenty of Room at the Bottom, Richard P. Feynman, http://www.zyvex.com/nanotech/feynman.html
3. Nanosystems: molecular machinery, manufacturing, and computation by K. Eric Drexler, Wiley 1992.

AM-974 OPTIMIZATION TECHNIQUES

4(L) - 0(T) - 0(P) - 4(Cr)

Optimization: Design variables, Design constraints, Objective function Design space, feasible region, Problem statement, Local and Global optima, Classification of optimization problems, Solution by calculus and numerical methods.

Linear Programming: Simplex method.

Geometric Programming: Application to simple problems.

Non-Linear Programming: Method of approximation programming, Kelly's Cutting Plane method.

Gradient Methods: Steepest descent and Side step method. Conjugate Gradient method, Rosin's Gradient Projection Method, Zotendik's method of feasible directions, Unconstrained minimization, penalty function technique search procedures.

Dynamic programming, Genetic Algorithm, Artificial Neural Network.

Application to problems of Process Equipment, Development of computer programmes.

References

1. S.S.Rao- Engineering Optimzation: Theory and Practice, New Age International Pvt. Limited
2. N.S.Kambo- Mathematical Programming Techniques- East-West Press.
3. H.A.Taha- Operation Research an Introduction, Prentice Hall.
4. L.C.W.Dixon- Nonlinear Optimization: Theory and Algorithms.
5. G.Hadley- Linear Programming Vol.I
6. G.Hadley- Nonlinear and Dynamic Programming Vol.II, Edison Wesley.

AM-976 ROBOTICS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction: History of Robot development, Laws of Robotics, Robot Classification, Components.

Robot Kinematics: Direct and inverse kinematics, Rotation Matrix, Composite Matrix, Denavit-Hartenberg representation, Robot Dynamics.

Drives, Sensors, Encoders and End effectors used in robotics.

Robot Trajectory Planning: Introduction, General considerations on trajectory planning, joint interpolated trajectories, planning of manipulator Cartesian path trajectories.

Robot intelligence and task planning.

References

1. K.S.Fu, R.C.Gonzalez, C.S.G.Lee-ROBOTICS:Control,Sensing,Vision and Intelligence; Mc Graw Hill Book Company.

2. Rex Miller- Fundamentals of Industrial Robots and Robotics;PWS-Kent Publishing Company

3. Phillip John McKerrow- Introduction to Robotics; Addison-Wesley Publishing Company

4. Mikell P Groover, Mitchell Weiss, Roger N. Negel, Nicholas G. Odrey-Industrial Robotics-Tcchnology, Programming and Applications; Mc Graw Hill Book Company

AM-977 SMART MATERIAL & SYSTEMS

4(L) - 0(T) - 0(P) - 4(Cr)

Introduction: Basic concepts of smartness, Definition and characteristics

Smart Behaviours and Materials: Piezoelectric, electrostrictive, magnetostrictive, pyroelectric, electrooptic, Piezomagnetism, Pyromagnetism, Piezoresitivity, Thermoelectricity, photon striction, shape memory alloy, Superelastic, Viscoelastic, Elastorestrictive, electrorheological, Thermochromic

Material properties and performance parameters: Phenomenology and constitutive relations

Material design and Engineering: crystal structure, phase diagram, Effect of various parameter on material behaviour

Smart composites: Introduction, working, application,

Material Synthesis: solid state reaction, sol-gel process

Measurement of properties: Testing and characterisation of materials,

Applications: Design and fabrication of devices and structures and their integration with system: Biomorphs/Moonies, Chip capacitor, Memory devices (FRAM), Sensor, actuator and transducers, Accelerometer, Gyroscopes, Ultrasonic Motor, Liquid Crystal display, Photonics, Structure Health Monitoring

Term Paper: On application/recent advances based on literature survey and/or lab/industry visit(s)

Books:

1. Ferroelectric devices- Kenji Uchino, Marcell Decker Inc., 2000

2. Adaptronics and Smart Structures- Basics, Design and Applications- Janocha Harmut (Ed.), Springer-Verlag Berlin Heidelberg, 1999

3. Smart Materials and Structures- M.V. Gandhi, B.S. Thompson, Chapman and Hall, London 1992

AM-978 THEORY OF STABILITY

4(L) - 0(T) - 0(P) - 4(Cr)

Concepts of Stability : Equilibrium path, Geometric Non linearity, Stability criteria.

Elastic Stability of bars : Columns with various loading and boundary conditions, Uniform and varying cross-sections, Beam – columns, Inelastic Stability of bars, Tangent Modulus, Double Modulus and Shanleys theories.

Elastica : Large Deformation Theory : Effect of Imperfections, Initial curvature, Eccentricity of loading, Residual stress.

Approximate Methods of Analysis : Principle of conservation of Energy, Principal of stationary Potential Energy, Rayleigh-Ritz Method, Galerkins method, Numerical methods.

Torsional Stability : Stability of Thin-walled open sections, buckling by torsion and torsion and Flexure.

Lateral Stability : Lateral stability of beams with various loadings and end conditions. Energy Methods.

Elastic Stability of Plates : Differential Equations of plate Buckling linear theory, stability of Rectangular plates under axial compression and shear, Effect of imperfections, Post-buckling behaviour of plants.

Elastic Stability of Cylindrical Shells : Stability of cylindrical shells under uniform axial pressure and torsion. Effect imperfections.

Experiments in Stability : South well Plot, Experimental and Design formulae.

References

1. Timoshenko and Gere-Theory of elastic Stability, Tata Mc-Graw Hills.
2. A.Chazes- Principle of Structural Stability Theory, Prentice Hall.
3. Bleich –Buckling Strength of Metal structures
4. Ashwani Kumar-Stability of Theory of Structures , Tata Mc-Graw Hills
5. H.G.Allen and P.S.Bulson- Background to Buckling, Mc-Graw Hill
6. N.G.R. Iyengar, Structural Stability of Columns and Plates, Affiliated East-West Press.