Maulana Azad National Institute of Technology Bhopal

Department of Mechanical Engineering

Syllabus of The Courses for M. Tech in Machine Design

Core Theory Courses:

ME MD 1101: Continuum Mechanics

Purpose:

The aim of this course is to expose students to the basic elements of continuum mechanics in a sufficiently rigorous manner. After attending this course, students should be able to appreciate a wide variety of advanced courses in solid and fluid mechanics. This course structure ensures a thorough understanding of continuum mechanics, equipping students with the necessary knowledge to pursue advanced studies in solid and fluid mechanics.

Lecturewise Breakup (40 lectures)

I. Introduction: (1 Lecture): Overview and significance of continuum mechanics

II. Mathematical Preliminaries: (6 Lectures): Vector and tensor calculus, Tensor analysis, derivatives of functions with respect to tensors, Fields: divergence (div), gradient (grad), curl, Divergence theorem, transport theorem

III. Kinematics: (6 Lectures): Configurations of a body, displacement, velocity, motion, Deformation gradient, rotation, stretch, strain, strain rate, spin tensor, Assumption of small deformation and small strain

IV. Balance Laws: (6 Lectures): Balances of mass, linear momentum, and angular momentum, Contact forces and the concept of stress, Balance of energy and Clausius-Duhem inequality

V. Constitutive Relation: (12 Lectures): Frame indifference, Material symmetry, Kinematic constraints (e.g., incompressibility), Thermodynamical restrictions

VI. Finite Elasticity: (5 Lectures): Hyperelasticity, isotropy, anisotropy, constitutive relations, strain energy functions, boundary value problems

VII. Viscoelasticity: (4 Lectures): Constitutive relations, modeling of viscoelastic material class, boundary value problems

Book References:

1. "Continuum Mechanics" by A. J. M. Spencer
2. "Continuum Mechanics" by P. Chadwick
3. "An Introduction to Continuum Mechanics" by M. E. Gurtin
4. "Introduction to the Mechanics of a Continuous Medium" by L. E. Malvern
5. "Continuum Mechanics" by C. S. Jog

ME MD 1102: Advanced Dynamics of Machines

Purpose:

The purpose of this course is to provide postgraduate students with an advanced understanding of the dynamic behavior of mechanical systems and machines. This includes in-depth study of complex dynamic interactions, analytical and numerical methods for dynamic analysis, and the application of these methods to real-world engineering problems. Students will develop the ability to model, analyze, and design mechanical systems with dynamic considerations.

Lecturewise Breakup (40 lectures):

I. Introduction (1 Lecture): Importance and applications of advanced dynamics in machine design.

II. Kinematics of Multi-Body Systems (6 Lectures): Coordinate systems and transformations, Kinematic constraints and degrees of freedom, Relative motion analysis, Kinematic analysis of planar and spatial mechanisms.

III. Dynamic Analysis of Multi-Body Systems (6 Lectures): Newton-Euler equations for multi-body systems, Lagrange's equations, Kane's method, Application to robotic systems and vehicle dynamics.

IV. Nonlinear Dynamics and Stability (6 Lectures): Nonlinear differential equations and stability, Phase plane analysis and bifurcation theory, Lyapunov's direct method, Chaos theory and its implications in mechanical systems.

V. Vibration Analysis of Continuous Systems (6 Lectures): Vibrations of strings, rods, and beams, Rayleigh-Ritz and Galerkin methods, Natural frequencies and mode shapes, Forced response and damping in continuous systems.

VI. Advanced Vibration Control (6 Lectures): Active and passive vibration control techniques, Design of vibration absorbers and dampers, Control of vibration in flexible structures, Smart materials and adaptive structures for vibration control.

VII. Rotordynamics (6 Lectures): Dynamics of rotating shafts and disks, Critical speeds and resonance in rotating machinery, Gyroscopic effects and their impact on stability, Balancing of rotors and diagnostic techniques.

VIII. Computational Methods in Dynamics (6 Lectures): Finite element analysis (FEA) in dynamic systems, multi-body dynamics software tools, Time integration methods for dynamic simulations, Model reduction techniques for large-scale dynamic systems.

IX. Experimental Techniques in Dynamics (3 Lectures): Modal analysis and identification, Vibration testing methods, Use of sensors and data acquisition systems, Experimental validation of dynamic models.

Book References:

1. "Engineering Vibration" by Daniel J. Inman

2. "Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering" by Steven H. Strogatz

3. "Dynamics of Multibody Systems" by Robert E. Roberson and Richard Schwertassek

4. "Principles of Vibration" by Benson H. Tongue

5. "Mechanical Vibrations" by Singiresu S. Rao

6. "Rotordynamics" by Agnieszka Muszyńska

7. "Theory of Vibration with Applications" by William T. Thomson and Marie Dillon Dahleh

<u>ME MD 1103: CAD and Finite Element Analysis</u>

Purpose:

The purpose of this course is to provide postgraduate students with an advanced understanding of Computer-Aided Design (CAD) and Finite Element Analysis (FEA). Students will learn to utilize CAD tools for complex design tasks and apply FEA for structural, thermal, and dynamic analysis. This course will enable students to model, analyze, and optimize mechanical systems using state-of-the-art CAD and FEA software.

Lecturewise Breakup (40 lectures):

I. Introduction to CAD and FEA (2 Lectures): Overview of CAD and its applications in engineering, Introduction to FEA and its significance in analysis.

II. Advanced CAD Techniques (12 Lectures): 3D modeling and surface design, Parametric modeling and feature-based design, Assembly modeling and interference checking, Design automation and scripting in CAD software.

III. Geometric Modeling (9 Lectures): Mathematical representation of curves and surfaces, Solid modeling techniques: B-rep, CSG, NURBS and Bezier surfaces, Mesh generation and refinement.

IV. Fundamentals of FEA (5 Lectures): Introduction to finite element method, Discretization and meshing strategies, Element types and shape functions, Formulation of stiffness matrices and load vectors.

V. Structural Analysis Using FEA (6 Lectures): Static analysis of trusses, beams, and frames, Stress and strain analysis in 2D and 3D, Modal analysis and natural frequencies, Buckling analysis of structures.

VII. Dynamic Analysis Using FEA (6 Lectures): Time-dependent dynamic analysis, Harmonic and transient response analysis, Vibration analysis and damping effects, Impact and crash analysis.

Book References:

1. "Introduction to Finite Elements in Engineering" by T. R. Chandrupatla and A. D. Belegundu

2. "Finite Element Procedures" by Klaus-Jürgen Bathe

3. "The Finite Element Method in Engineering" by S. S. Rao

4. "Engineering Analysis with ANSYS Software" by T. S. Liu and M. B. Liu

5. "Computer-Aided Design and Manufacturing" by Mikell P. Groover and Emory W. Zimmers Jr.

6. "Geometric Modeling" by Michael E. Mortenson

ME MD 1201: Design and Optimization

Purpose:

The purpose of this course is to provide postgraduate students with an advanced understanding of design and optimization techniques applied to machine elements and structures. Students will learn to design machine components based on strength and distortion criteria, select appropriate materials, and apply advanced optimization methods. This course aims to equip students with the skills necessary for designing reliable and efficient mechanical systems and optimizing their performance through classical and numerical methods.

Lecturewise Breakup (40 lectures):

I. Review of Machine Element Design (6 Lectures): Design based on strength and distortion criteria, Review of material selection and treatment, Designing for fatigue and creep, Design criteria for fracture.

II. Advanced Design Criteria for Machine Elements (6 Lectures): Application to shafts, spur gears, bevel gears, and worm gears, Design of structures, machines, and equipment, Case studies on the application of advanced design criteria.

III. Classical Methods of Unconstrained Optimization (6 Lectures): Optimization in single variable, Optimization in multiple variables, Techniques and applications of classical unconstrained optimization.

IV. Classical Methods of Constrained Optimization (6 Lectures): Optimization with equality constraints, Optimization with inequality constraints, Techniques and applications of classical constrained optimization.

V. Numerical Optimization Techniques (8 Lectures): Introduction to numerical optimization, Genetic algorithms (binary and real-coded), Simulated annealing, Other numerical optimization methods (e.g., particle swarm optimization, differential evolution).

VI. Applications and Case Studies in Optimum Design (8 Lectures): Optimum design of gearboxes, Power transmission systems optimization, Shape and topology optimization using finite element analysis (FEA), Case studies demonstrating the use of optimization in real-world engineering problems.

Book References:

1. "Mechanical Engineering Design" by J.E. Shigley and C.R. Mischke

2. "Design of Machine Elements" by V. B. Bhandari

3. "Engineering Optimization: Theory and Practice" by S. S. Rao

4. "Optimization for Engineering Design: Algorithms and Examples" by Kalyanmoy Deb

5. "Introduction to Optimum Design" by Jasbir S. Arora

6. "Genetic Algorithms in Search, Optimization, and Machine Learning" by David E. Goldberg

7. "Simulated Annealing: Theory and Applications" by P.J. van Laarhoven and E.H. Aarts

ME MD 1202: Tribology and Rotor Dynamics

Purpose:

The purpose of this course is to provide postgraduate students with an in-depth understanding of the principles and applications of tribology and rotor dynamics. Students will explore the mechanisms of friction, lubrication, and wear, and analyze the dynamic behavior of rotating machinery. This course equips students with the knowledge and skills needed to address complex issues in machine design and maintenance.

Lecturewise Breakup (40 lectures)

I. Introduction to Tribology (2 Lectures): Definition and significance of tribology, Historical development and applications in engineering.

II. Friction (6 Lectures): Laws of friction, Types of friction: static, kinetic, and rolling, Theories of friction: adhesion and deformation, Measurement of friction and frictional materials.

III. Lubrication (8 Lectures): Types of lubrication: hydrodynamic, hydrostatic, elastohydrodynamic, and boundary lubrication, Lubricants: properties and selection criteria, Lubrication regimes and applications, Design of journal bearings and thrust bearings.

IV. Wear (6 Lectures): Types of wear: abrasive, adhesive, corrosive, and fatigue wear, Wear mechanisms and theories, Wear measurement techniques, Materials for wear resistance.

V. Surface Engineering (4 Lectures): Surface roughness and texture, Surface treatments: coatings, heat treatment, and surface modifications, Tribological properties of surfaces, Applications of surface engineering in industry.

VI. Introduction to Rotor Dynamics (2 Lectures): Overview of rotor dynamics, Applications in turbomachinery, power generation, and automotive engineering.

VII. Dynamics of Rotating Machinery (6 Lectures): Rigid and flexible rotors, Critical speeds and resonance, Gyroscopic effects, Rotor balancing techniques.

VIII. Vibration Analysis in Rotating Systems (6 Lectures): Sources of vibration in rotating machinery, Vibration measurement and analysis techniques, Modal analysis of rotors, Vibration control and mitigation strategies.

IX. Condition Monitoring and Fault Diagnosis (4 Lectures): Techniques for condition monitoring of rotating machinery, Fault diagnosis methods, Prognostics and health management, Case studies and industrial applications.

Book References:

1. "Engineering Tribology" by Gwidon Stachowiak and Andrew W. Batchelor

2. "Principles and Applications of Tribology" by Bharat Bhushan

3. "Tribology: Friction and Wear of Engineering Materials" by Ian Hutchings and Philip Shipway

4. "Rotor Dynamics" by J. S. Rao

5. "Rotordynamics Prediction in Engineering" by Michel Lalanne and Guy Ferraris

6. "Handbook of Rotordynamics" by Frederic M. Nelson and Agnieszka Muszyńska

Departmental Elective Courses:

ME MD 1151: Nonlinear Dynamics and Chaos

Purpose:

The purpose of this course is to provide postgraduate students with an in-depth understanding of the principles and applications of nonlinear dynamics and chaos. Students will explore the behavior of nonlinear systems, the emergence of chaotic dynamics, and methods for analyzing and controlling chaos. This course equips students with the knowledge and skills needed to tackle complex dynamic systems in various engineering and scientific fields.

Lecturewise Breakup (40 lectures):

I. Introduction to Nonlinear Dynamics (4 Lectures): Overview of linear vs. nonlinear systems, Historical development and significance of nonlinear dynamics, Examples of nonlinear systems in engineering and science.

II. Mathematical Foundations (6 Lectures): Review of differential equations and phase space, Fixed points, stability, and bifurcations, Linearization and local analysis of nonlinear systems, Perturbation methods and multiple scales analysis.

III. Bifurcation Theory (6 Lectures): Classification of bifurcations: saddle-node, transcritical, pitchfork, and Hopf bifurcations, Center manifold theory, Normal forms and unfolding of bifurcations, Applications of bifurcation theory in engineering.

IV. Chaotic Dynamics (8 Lectures): Definition and characteristics of chaos, Sensitivity to initial conditions and strange attractors, Routes to chaos: period-doubling, intermittency, and quasiperiodicity, Examples of chaotic systems: Lorenz system, logistic map, and Duffing oscillator.

V. Fractals and Strange Attractors (6 Lectures): Introduction to fractals and self-similarity, Fractal dimension and measures, Construction and properties of strange attractors, Applications of fractals in nature and technology.

VI. Lyapunov Exponents and Chaos Quantification (4 Lectures): Definition and calculation of Lyapunov exponents, Invariant measures and ergodic theory, Quantifying chaos using Lyapunov exponents, Practical examples and numerical methods.

VII. Nonlinear Time Series Analysis (4 Lectures): Introduction to time series and data analysis, Phase space reconstruction and embedding theorems, Techniques for detecting chaos in experimental data, Applications in engineering, biology, and finance.

VIII. Control and Synchronization of Chaos (2 Lectures): Methods for controlling chaos: OGY method, Pyragas control, Synchronization of chaotic systems, Applications in secure communications and engineering systems.

IX. Applications and Case Studies: (4 Lectures): Real-world applications of nonlinear dynamics and chaos, Case studies in mechanical systems, electrical circuits, and ecological models, Emerging research areas and future trends.

Book References:

1. "Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering" by Steven H. Strogatz

2. "Chaos: An Introduction to Dynamical Systems" by Kathleen Alligood, Tim Sauer, and James A. Yorke

3. "Nonlinear Dynamics and Chaos" by J. M. T. Thompson and H. B. Stewart

4. "Differential Equations, Dynamical Systems, and an Introduction to Chaos" by Morris W. Hirsch, Stephen Smale, and Robert L. Devaney

5. "Chaos and Fractals: New Frontiers of Science" by Heinz-Otto Peitgen, Hartmut Jürgens, and Dietmar Saupe

ME MD 1152: Theory of Plates and Shells

Purpose:

The Theory of Plates and Shells course aims to provide students with a thorough understanding of the behavior, analysis, and design of plate and shell structures. This course covers the fundamental principles, mathematical formulations, and practical applications essential for engineering problems involving plates and shells.

Lecturewise Breakup (40 lectures):

I. Introduction to Plates and Shells (2 Lectures): Overview and importance of plates and shells in engineering, Classification and applications of plate and shell structures.

II. Classical Plate Theory (CPT) (8 Lectures): Assumptions and derivation of governing equations, Boundary conditions and solution techniques, Bending of rectangular and circular plates, Navier's solution and Levy's solution, Applications and examples.

III. Shear Deformation Theory (SDT) (6 Lectures): Limitations of Classical Plate Theory, First-order Shear Deformation Theory (FSDT), Higher-order Shear Deformation Theories (HSDT), Comparison of CPT and SDT results, Practical applications and examples.

IV. Buckling of Plates (4 Lectures): Stability analysis and critical load determination, Buckling of simply supported, clamped, and free plates, Post-buckling behavior and design considerations.

V. Introduction to Shells (2 Lectures): Shell geometry and classifications, Basic concepts and assumptions in shell theory.

VI. Membrane Theory of Shells (4 Lectures): Membrane stresses and equilibrium equations, Analysis of cylindrical, spherical, and conical shells, Applications in engineering design.

VII. Bending Theory of Shells (8 Lectures): Bending and stretching of thin shells, Derivation of Donnell-Mushtari-Vlasov (DMV) equations, Solutions for cylindrical, spherical, and conical shells, Boundary conditions and practical examples.

VIII. Buckling of Shells (4 Lectures): Stability analysis and critical load determination, Buckling of cylindrical and spherical shells, Design considerations for buckling resistance.

IX. Advanced Topics and Applications (2 Lectures): Composite plates and shells, Functionally graded materials (FGMs), Nonlinear analysis and finite element methods (FEM) in plate and shell structures.

Book References:

1. "Theory of Plates and Shells" by Stephen P. Timoshenko and S. Woinowsky-Krieger

2. "Thin Plates and Shells: Theory, Analysis, and Applications" by Eduard Ventsel and Theodor Krauthammer

3. "Plates and Shells: Theory and Analysis" by Ansel C. Ugural

4. "Advanced Mechanics of Plates and Shells" by Madhujit Mukhopadhyay

5. "Theory of Elastic Stability" by Stephen P. Timoshenko and James M. Gere

ME MD 1153: Design of Pressure Vessels and Pipes

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in the design, analysis, and optimization of pressure vessels and piping systems. Students will learn about the principles governing the design of pressure vessels to ensure safety, efficiency, and reliability in various industrial applications. The course will cover both theoretical foundations and practical aspects of designing pressure vessels and pipes under different operating conditions.

Lecturewise Breakup (40 lectures):

I. Introduction to Pressure Vessels (2 Lectures): Overview of pressure vessels: types and applications, Importance of design standards and regulations.

II. Stress Analysis and Design Criteria (6 Lectures): Stress and strain analysis in pressure vessels, Design considerations: material selection, loading conditions, Design codes and standards: ASME Boiler and Pressure Vessel Code, API standards.

III. Design of Thin-Walled Pressure Vessels (8 Lectures): Cylindrical and spherical shells: analysis and design, Design for internal and external pressure, Reinforcement of openings and nozzles.

IV. Design of Thick-Walled Pressure Vessels (6 Lectures): Analysis and design of vessels subjected to combined loading, Effect of temperature and corrosion on thick-walled vessels, Design of heads, closures, and supports.

V. Piping Systems Design (6 Lectures): Piping layout and design considerations, Stress analysis in piping systems, Pipe supports and restraints.

VI. Finite Element Analysis (FEA) of Pressure Vessels and Pipes (6 Lectures): Application of FEA in stress analysis of vessels and pipes, Modeling techniques and boundary conditions, Interpretation of FEA results and validation.

VII. Fatigue and Fracture Mechanics in Design (4 Lectures): Fatigue analysis and life prediction methods, Fracture mechanics: critical flaw size, stress intensity factor, Failure analysis and prevention.

VIII. Safety, Reliability, and Maintenance (4 Lectures): Safety factors and risk assessment, Reliability-based design principles, Maintenance strategies for pressure vessels and pipes.

Book References:

1. "Pressure Vessel Design Manual" by Dennis R. Moss and Michael M. Basic

2. "Process Plant Equipment: Operation, Control, and Reliability" by Michael D. Holloway and Chikezie Nwaoha

3. "Piping Systems Manual" by Brian Silowash

4. "ASME Boiler and Pressure Vessel Code" (Various Sections)

5. "API Standards for Pressure Vessels and Piping" (Various Sections)

<u>ME MD 1154: Applied Elasticity and Plasticity</u>

Purpose:

The course on Applied Elasticity and Plasticity aims to provide students with a comprehensive understanding of the fundamental principles and applications of elasticity and plasticity in engineering materials. This course covers both theoretical foundations and practical techniques necessary for analyzing and designing structures subjected to mechanical loading.

Lecturewise Breakup (40 lectures):

I. Introduction to Elasticity and Plasticity (2 Lectures): Definition and significance in engineering applications, Overview of stress, strain, and deformation.

II. Mathematical Preliminaries (3 Lectures): Review of tensor calculus and vector analysis, Stress and strain tensors, Equilibrium equations and compatibility conditions.

III. Linear Elasticity (8 Lectures): Constitutive equations: Hooke's law, Plane stress and plane strain conditions, Elastic behavior of isotropic and anisotropic materials, Stress concentrations and stress intensity factors, Applications in structural analysis.

IV. Nonlinear Elasticity (5 Lectures): Elastic-plastic deformation, Elastic-plastic stress-strain relationships, Plastic yield criteria: Von Mises, Tresca, and others.

V. Plasticity Theory (7 Lectures): Yield criteria and plastic flow rules, Plastic deformation mechanisms: Dislocation theory, Strain hardening and recovery, Applications in metal forming and structural design.

VI. Creep (4 Lectures): Creep mechanisms and time-dependent deformation, Creep curves and constitutive models.

VII. Applications of Elasticity and Plasticity (6 Lectures): Stress analysis in beams, plates, and shells, Contact mechanics and frictional interfaces, Plasticity in manufacturing processes, Structural integrity and failure analysis.

VIII. Experimental Techniques in Elasticity and Plasticity (5 Lectures): Strain measurement techniques: Strain gauges, extensometers, Stress analysis methods: Photoelasticity, Moiré interferometry, Mechanical testing of materials under static and dynamic loading.

Book References:

1. "Elasticity: Theory, Applications, and Numerics" by Martin H. Sadd

2. "Plasticity for Structural Engineers" by W. F. Chen and E. M. Lui

3. "Introduction to Continuum Mechanics" by W. Michael Lai, David Rubin, and Erhard Krempl

4. "Mechanical Behavior of Materials" by Marc André Meyers and Krishan Kumar Chawla

5. "Introduction to the Mechanics of Solids" by Stephen H. Crandall and Norman C. Dahl

ME MD 1155: Aerodynamical Structural Designs

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in the design and analysis of aerodynamically optimized structures. Students will learn about the integration of aerodynamics with structural design principles to achieve efficient and reliable aerospace and mechanical systems. The course covers theoretical foundations, computational methods, and practical applications in aerodynamic structural design.

Lecturewise Breakup (40 lectures):

I. Fundamentals of Aerodynamics (4 Lectures): Overview of aerodynamic forces and moments, Flow regimes: subsonic, transonic, supersonic, and hypersonic, Airfoil and wing theory.

II. Structural Mechanics for Aerodynamic Design (6 Lectures): Stress and strain analysis in aerospace structures, Composite materials for lightweight structures, Structural dynamics and aeroelasticity.

III. Wing Design (8 Lectures): Wing geometry and aerodynamic performance metrics, Airfoil selection and optimization, Wing loading and lift distribution.

IV. Fuselage and Body Design (6 Lectures): Fuselage aerodynamics and drag reduction techniques, Structural layout and integration with aerodynamic requirements, Design considerations for high-speed and maneuverable aircraft.

V. Computational Fluid Dynamics (CFD) in Structural Design (8 Lectures): Introduction to CFD methods and numerical techniques, Applications of CFD in aerodynamic analysis, Aerostructural optimization using CFD-aided design tools.

VI. Aerodynamic Stability and Control (4 Lectures): Static and dynamic stability analysis, Control surface design and optimization, Maneuverability and flight control systems.

VII. Advanced Topics in Aerodynamic Structural Design (4 Lectures): Wingtip devices and boundary layer control, Morphing structures for adaptive aerodynamics, Integration of propulsion systems with aerodynamic design.

VIII. Case Studies and Applications (4 Lectures): Case studies of aerodynamic structural design in commercial and military aircraft, Application to unmanned aerial vehicles (UAVs) and space vehicles, Emerging trends and future directions in aerodynamic design.

Book References:

1. "Aircraft Design: A Conceptual Approach" by Daniel P. Raymer

2. "Introduction to Aircraft Aeroelasticity and Loads" by Jan R. Wright and Jonathan E. Cooper

3. "Fundamentals of Aerodynamics" by John D. Anderson Jr.

4. "Aircraft Structures for Engineering Students" by T.H.G. Megson

5. "Aerodynamics for Engineering Students" by E.L. Houghton and P.W. Carpenter

ME MD 1161: Design against Fatigue and Fracture

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in designing engineering components and structures to withstand fatigue and fracture. Students will learn about the underlying mechanisms of fatigue and fracture, as well as advanced methodologies for design, analysis, and prevention of failure due to these mechanisms. The course will cover theoretical foundations, practical design considerations, and state-of-the-art techniques used in industries such as aerospace, automotive, and structural engineering.

Lecturewise Breakup (40 lectures):

I. Introduction to Fatigue and Fracture Mechanics (4 Lectures): Definition and classification of fatigue and fracture, Importance of fatigue and fracture mechanics in engineering design, Failure modes: brittle fracture, ductile fracture, fatigue crack growth.

II. Mechanisms of Fatigue (6 Lectures): Fatigue life prediction methods: S-N curve, stress-life approach, Crack initiation and propagation under cyclic loading, Environmental effects on fatigue behavior.

III. Mechanisms of Fracture (6 Lectures): Types of fracture: brittle, ductile, fatigue-induced, Fracture toughness and critical flaw size, Stress concentration and notch sensitivity.

IV. Design against Fatigue (8 Lectures): Design criteria for fatigue resistance, Material selection and enhancement techniques: surface treatments, shot peening, welding techniques, Fatigue testing and data analysis.

V. Design against Fracture (8 Lectures): Fracture mechanics principles: stress intensity factor, crack growth analysis, Design with respect to critical crack size and residual stresses, Case studies of fracture-resistant designs.

VI. Advanced Topics in Fatigue and Fracture (4 Lectures): High-cycle fatigue vs. low-cycle fatigue, Creep-fatigue interaction, Probabilistic methods in fatigue and fracture analysis.

VII. Advanced Techniques for Design Optimization (4 Lectures): Finite Element Analysis (FEA) for fatigue and fracture analysis, Optimization techniques: genetic algorithms, simulated annealing, Multidisciplinary design optimization (MDO) for fatigue-prone structures.

VIII. Applications and Case Studies (4 Lectures): Case studies of fatigue and fracture failures in engineering components, Design solutions in aerospace, automotive, and marine industries, Emerging trends and future directions in fatigue and fracture design.

Book References:

1. "Fatigue of Structures and Materials" by J. F. Maddox

2. "Mechanical Behavior of Materials" by Norman E. Dowling

3. "Fracture Mechanics: Fundamentals and Applications" by T. L. Anderson

4. "Introduction to the Mechanics of a Continuous Medium" by L. E. Malvern

5. "Practical Stress Analysis with Finite Elements" by Bryan J. Mac Donald

<u>ME MD 1162: EV System Design and Architecture</u>

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in the design and architecture of Electric Vehicle (EV) systems. Students will explore the interdisciplinary aspects of EV technology, including power electronics, energy storage systems, electric propulsion systems, and vehicle integration. The course aims to prepare students for careers in automotive engineering, renewable energy systems, and sustainable transportation industries.

Lecturewise Breakup (40 lectures):

I. Introduction to Electric Vehicles (4 Lectures): Overview of electric vehicle architectures: BEVs, PHEVs, HEVs, Importance of EVs in reducing carbon footprint and sustainable transportation.

II. Electric Propulsion Systems (6 Lectures): Components of electric propulsion systems: electric motors, motor controllers, Powertrain architectures and efficiency considerations, Comparison with internal combustion engines.

III. Energy Storage Systems (6 Lectures): Battery technologies for EVs: lithium-ion, solid-state, and emerging technologies, Battery management systems (BMS) and thermal management, Charging infrastructure: fast charging vs. slow charging.

IV. Power Electronics in EVs (6 Lectures): Power converters: DC-DC converters, inverters, Control strategies for efficient power conversion, Integration of power electronics with vehicle systems.

V. Vehicle Dynamics and Control (6 Lectures): Dynamics of electric vehicles: traction control, regenerative braking, Stability and handling considerations in EV design, Autonomous driving and sensor integration.

VI. EV System Integration and Architecture (8 Lectures): Integration of electric propulsion, energy storage, and power electronics, Vehicle architecture design: platform-based vs. bespoke designs, Safety and reliability considerations in EV architecture.

VII. Advanced Topics in EV Design (4 Lectures): Vehicle-to-Grid (V2G) technology and smart grid integration, Emerging trends in EV technology: wireless charging, battery recycling, Environmental impact assessment and life cycle analysis of EVs.

VIII. Case Studies and Industry Applications (4 Lectures): Case studies of commercial EV platforms: Tesla, Nissan Leaf, BMW i series, Design challenges and solutions in electric vehicle manufacturing, Regulatory requirements and standards for EVs.

Book References:

1. "Electric Vehicle Technology Explained" by James Larminie and John Lowry

2. "Electric and Hybrid Vehicles: Design Fundamentals" by Iqbal Husain

3. "Power Electronics and Motor Drives: Advances and Trends" by Bimal K. Bose

4. "Battery Management Systems for Large Lithium Ion Battery Packs" by John Pilla

ME MD 1163: Biomechanics and Materials

Purpose:

The course on Biomechanics and Materials aims to provide students with a comprehensive understanding of the mechanical behavior of biological tissues and the materials used in biomedical applications. Emphasis is placed on the principles of mechanics applied to biological systems and the properties and applications of biomaterials.

Lecturewise Breakup (40 lectures):

I. Introduction to Biomechanics (3 Lectures): Overview of biomechanics and its significance in engineering and medicine, Basic concepts: Stress, strain, and mechanical properties, Differences between biological and synthetic materials.

II. Mechanical Properties of Biological Tissues (7 Lectures): Structure and function of biological tissues: Bone, cartilage, muscle, tendon, and ligament, Viscoelasticity and time-dependent behavior of biological tissues, Anisotropy and heterogeneity in biological tissues, Mechanical testing of biological tissues: Tension, compression, and shear tests.

III. Biomechanics of Bone and Soft Tissues (6 Lectures): Mechanical properties and behavior of bone, Fracture mechanics and healing of bone, Mechanics of soft tissues: Skin, arteries, and organs, Biomechanics of joints and connective tissues.

IV. Cardiovascular Biomechanics (5 Lectures): Mechanics of blood flow and the cardiovascular system, Hemodynamics and fluid-structure interactions, Biomechanics of the heart and blood vessels, Applications in cardiovascular device design.

V. Orthopedic Biomechanics (5 Lectures): Mechanics of the musculoskeletal system, Biomechanics of implants and prosthetics, Load transfer and stress distribution in orthopedic devices, Applications in orthopedic surgery and rehabilitation.

VI. Introduction to Biomaterials (4 Lectures): Classification and properties of biomaterials: Metals, ceramics, polymers, and composites, Biocompatibility and biological response to biomaterials, Surface properties and modifications of biomaterials.

VII. Biomaterials in Medical Applications (6 Lectures): Biomaterials for orthopedic applications: Bone grafts, joint replacements, Cardiovascular biomaterials: Stents, heart valves, vascular grafts, Dental biomaterials: Fillings, crowns, and implants, Soft tissue replacements: Skin substitutes, wound dressings.

VIII. Tissue Engineering and Regenerative Medicine (4 Lectures): Principles of tissue engineering and scaffold design, Biomaterials for tissue engineering applications, Cell-material interactions and tissue regeneration, Applications in regenerative medicine.

Book References:

1. "Biomechanics: Mechanical Properties of Living Tissues" by Y.C. Fung

2. "Fundamentals of Biomechanics" by Duane Knudson

3. "Introduction to Biomedical Engineering" by John Enderle and Joseph Bronzino

4. "Biomaterials: The Intersection of Biology and Materials Science" by Johnna S. Temenoff and Antonios G. Mikos

5. "Tissue Engineering" by Clemens Van Blitterswijk

<u>ME MD 1164: Condition Monitoring</u>

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in the theory, techniques, and applications of condition monitoring for mechanical and electrical systems. Students will learn about various monitoring methods, diagnostic tools, and predictive maintenance strategies used to assess the health and performance of industrial machinery and equipment. The course aims to prepare students for careers in maintenance engineering, reliability engineering, and industrial automation.

Lecturewise Breakup (40 lectures):

I. Introduction to Condition Monitoring (4 Lectures): Definition and importance of condition monitoring in industrial systems, Objectives: early fault detection, predictive maintenance, asset management.

II. Fundamentals of Machine Condition (6 Lectures): Types of machine faults: mechanical, electrical, fluid systems, Failure modes and effects analysis (FMEA) and fault tree analysis (FTA).

III. Sensors and Data Acquisition (6 Lectures): Types of sensors used in condition monitoring: vibration sensors, temperature sensors, pressure sensors, Signal conditioning and data acquisition systems,Wireless sensor networks and IoT in condition monitoring.

IV. Vibration Analysis (8 Lectures): Basics of vibration: frequency, amplitude, phase, Vibration measurement techniques: FFT analysis, time-domain analysis, Fault diagnosis through vibration signatures.

V. Oil Analysis and Tribology (6 Lectures): Importance of lubrication and oil analysis in machinery health, Tribological principles: wear debris analysis, oil viscosity, contamination, Condition monitoring of bearings, gears, and hydraulic systems.

VI. Thermography and Infrared Imaging (4 Lectures): Principles of thermography in condition monitoring, Application of infrared imaging for heat detection and anomaly identification, Case studies in thermal analysis for predictive maintenance.

VII. Electrical Condition Monitoring (4 Lectures): Insulation resistance testing and dielectric analysis, Motor current signature analysis (MCSA) and electrical fault diagnosis, Condition monitoring of transformers and electrical distribution systems.

VIII. Data Analysis and Predictive Maintenance (4 Lectures): Statistical methods for condition assessment: trend analysis, pattern recognition, Predictive maintenance strategies: condition-based, reliability-centered, Integration of condition monitoring with maintenance management systems.

Book References:

1. "Machinery Condition Monitoring: Principles and Practices" by Amiya Ranjan Mohanty

2. "Vibration Monitoring, Testing, and Instrumentation" by Clarence W. de Silva

3. "Handbook of Condition Monitoring: Techniques and Methodology" edited by R. S. Chakraborty

4. "Introduction to Predictive Maintenance" by R. Keith Mobley

ME MD 1165: Friction and Wear in Machinery

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in understanding the principles, mechanisms, and management of friction and wear in machinery. Students will explore the underlying physics of friction and wear, various types of wear mechanisms, and strategies for minimizing wear and optimizing tribological performance in mechanical systems. The course aims to prepare students for careers in mechanical engineering, materials science, and industrial maintenance.

Lecturewise Breakup (40 lectures):

I. Introduction to Friction and Wear (4 Lectures): Definition and significance of friction and wear in machinery, Historical developments and industrial applications.

II. Fundamentals of Tribology (6 Lectures): Tribological interfaces: surfaces, lubricants, contact mechanics, Types of friction: static, kinetic, rolling, sliding, Theories of friction: adhesion, deformation, lubrication.

III. Wear Mechanisms (8 Lectures): Types of wear: abrasive, adhesive, erosive, corrosive, and fatigue wear, Wear mechanisms at tribological interfaces, Wear testing methods and standards.

IV. Lubrication and Surface Treatments (6 Lectures): Role of lubricants in reducing friction and wear, Types of lubrication: boundary, mixed, hydrodynamic, and elastohydrodynamic lubrication, Surface treatments for wear resistance: coatings, hardening processes, surface modifications.

V. Friction and Wear in Specific Components (8 Lectures): Bearings and sliding surfaces: design considerations and materials selection, Gears and gearboxes: wear mechanisms and lubrication requirements, Seals and gaskets: sealing technologies and wear prevention.

VI. Advanced Topics in Friction and Wear (4 Lectures): Tribo-corrosion: interaction between wear and corrosion, Nanotribology: effects of surface roughness and nano-scale interactions, Wear in extreme environments: high temperatures, vacuum, space.

VII. Monitoring and Diagnostics of Friction and Wear (4 Lectures): Condition monitoring techniques for detecting wear, Wear debris analysis and predictive maintenance strategies, Case studies of wear-related failures in industrial machinery.

VIII. Applications and Case Studies (4 Lectures): Case studies of friction and wear management in automotive, aerospace, and manufacturing industries, Design considerations for minimizing friction and wear in specific applications, Emerging trends and future directions in tribology research.

Book References:

1. "Engineering Tribology" by Gwidon Stachowiak and Andrew W. Batchelor

2. "Principles and Applications of Tribology" by Bharat Bhushan

3. "Tribology: Friction and Wear of Engineering Materials" by Ian Hutchings and Philip Shipway

4. "Introduction to Tribology" by Bharat Bhushan

ME MD 1251: Dynamics of Multibody Systems

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in the dynamics and simulation of multibody systems. Students will learn theoretical foundations, numerical techniques, and practical applications related to the analysis of interconnected rigid and flexible bodies in mechanical systems. The course aims to prepare students for careers in robotics, vehicle dynamics, biomechanics, and aerospace engineering.

Lecturewise Breakup (40 lectures):

I. Introduction to Multibody Dynamics (4 Lectures): Definition and significance of multibody systems, Applications in mechanical engineering, robotics, and biomechanics, Historical developments and current trends.

II. Kinematics of Multibody Systems (6 Lectures): Coordinate systems and generalized coordinates, Position, velocity, and acceleration analysis of rigid bodies, Recursive methods and kinematic constraints.

III. Dynamics of Rigid Multibody Systems (8 Lectures): Newton-Euler equations of motion for rigid bodies, Kane's method and Lagrange's equations, Constraint equations and holonomic/nonholonomic constraints.

IV. Flexible Multibody Systems (6 Lectures): Introduction to flexible body dynamics, Finite Element Method (FEM) and modal analysis, Coupled rigid-flexible dynamics and mode superposition techniques.

V. Contact Mechanics and Collision Handling (6 Lectures): Contact models and force laws in multibody systems, Impact analysis and restitution coefficients, Frictional contact and contact detection algorithms.

VI. Numerical Integration Methods (4 Lectures): Time integration schemes: explicit vs. implicit methods, Stability and accuracy considerations in dynamic simulations, Integration with differential algebraic equations (DAE).

VII. Control and Stability of Multibody Systems (4 Lectures): Feedback control strategies in multibody dynamics, Stability analysis and Lyapunov stability criteria, Applications in robotic manipulators and vehicle stability control.

VIII. Applications and Case Studies (4 Lectures): Case studies of multibody dynamics in robotics and biomechanics, Simulation of vehicle dynamics and suspension systems, Biomechanical models for human movement analysis.

Book References:

1. "Dynamics of Multibody Systems" by Jens Wittenburg

2. "Computational Dynamics" by Ahmed A. Shabana

3. "Multibody Dynamics: Computational Methods and Applications" by Garcia de Jalón and Bayo

4. "Robot Dynamics and Control" by Mark W. Spong, Seth Hutchinson, and M. Vidyasagar

<u>ME MD 1252: Design of Advanced Mechanisms</u>

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in the design, analysis, and optimization of complex mechanical systems and mechanisms. Students will explore theoretical principles, computational methods, and practical applications related to the design of advanced mechanisms used in robotics, automation, aerospace, and precision engineering.

Lecturewise Breakup (40 lectures):

I. Introduction to Advanced Mechanisms (4 Lectures): Definition and significance of advanced mechanisms, Historical developments and applications in modern engineering, Challenges and requirements in designing advanced mechanical systems.

II. Kinematic Analysis of Mechanisms (6 Lectures): Mobility and types of kinematic pairs, Graphical and analytical methods for kinematic analysis, Path, velocity, and acceleration analysis of mechanisms.

III. Dynamics of Mechanisms (6 Lectures): Newton-Euler equations for rigid body dynamics, Lagrangian formulation and Kane's method for multibody dynamics, Dynamic force analysis and inertial properties of mechanisms.

IV. Mechanism Synthesis and Design (8 Lectures): Design synthesis techniques: dimensional synthesis, path synthesis, and function generation, Optimization methods in mechanism design: genetic algorithms, simulated annealing, Case studies in mechanism design optimization.

V. Advanced Mechanism Types (6 Lectures): Parallel mechanisms: analysis and design considerations, Spatial mechanisms and robots: kinematics and workspace analysis, Hybrid mechanisms: combinations of serial and parallel mechanisms.

VI. Motion Control and Actuation (4 Lectures): Actuator selection and sizing: electric motors, hydraulic actuators, pneumatic actuators, Motion control strategies: PID control, trajectory planning, Feedback control systems in advanced mechanisms.

VII. Applications in Robotics and Automation (4 Lectures): Design of robotic manipulators: serial and parallel configurations, Mechanisms for automated manufacturing and assembly, Case studies of advanced mechanisms in industry.

VIII. Emerging Trends and Future Directions (2 Lectures): Advances in mechanism design: soft robotics, compliant mechanisms, Integration of sensors and smart materials in advanced mechanisms, Industry 4.0 and the impact on advanced mechanism design.

Book References:

1. "Mechanical Design of Machine Elements and Machines" by Jack A. Collins, Henry R. Busby, and George H. Staab

2. "Mechanisms and Mechanical Devices Sourcebook" by Neil Sclater and Nicholas Chironis

3. "Advanced Mechanism Design: Analysis and Synthesis Vol. II" by Sandor and Erdman

4. "Mechatronics: Principles and Applications" by Godfrey C. Onwubolu

ME MD 1253: Industrial Instrumentation and Control

Purpose:

The purpose of this course is to provide postgraduate students with advanced knowledge and skills in industrial instrumentation and control systems used in modern manufacturing and process industries. Students will learn about sensors, measurement techniques, control strategies, and automation technologies essential for monitoring and optimizing industrial processes.

Lecturewise Breakup (40 lectures):

I. Introduction to Industrial Instrumentation (4 Lectures): Definition and scope of industrial instrumentation and control, Importance in modern manufacturing and process industries, Overview of sensors, transducers, and signal conditioning.

II. Sensors and Measurement Systems (8 Lectures): Types of sensors: temperature, pressure, level, flow, and position sensors, Selection criteria and characteristics of sensors, Signal conditioning techniques: amplification, filtering, and digital conversion.

III. Data Acquisition Systems (6 Lectures): Analog and digital data acquisition systems, Sampling theorem and anti-aliasing filters, Communication protocols: RS-232, RS-485, Ethernet, and Fieldbus systems.

IV. Process Control Fundamentals (6 Lectures): Control system components: controllers, actuators, and final control elements, Open-loop vs. closed-loop control systems, PID control: principles and tuning methods.

V. Advanced Control Strategies (8 Lectures): Model-based control: MPC (Model Predictive Control) and adaptive control, Fuzzy logic control and neural network-based control, Distributed control systems (DCS) and supervisory control and data acquisition (SCADA) systems.

VI. Industrial Automation (4 Lectures): Programmable Logic Controllers (PLCs): programming, operation, and applications, Human-Machine Interface (HMI) design and integration, Integration of sensors, actuators, and control systems in industrial automation.

VII. Instrumentation in Hazardous Environments (2 Lectures): Safety considerations in hazardous environments: intrinsically safe systems, Explosion-proof instrumentation and certification standards.

VIII. Case Studies and Applications (2 Lectures): Case studies of instrumentation and control systems in manufacturing, chemical, and power industries, Applications of advanced control systems in process optimization and energy efficiency.

Book References:

1. "Instrumentation and Control Systems" by William Bolton

2. "Process Control: Modeling, Design, and Simulation" by B. Wayne Bequette

3. "Industrial Instrumentation" by Donald P. Eckman

4. "PLC Programming using RSLogix 5000" by Gary Dunning

ME MD 1254: Automotive Design

Purpose:

The course on Automotive Design aims to provide students with an in-depth understanding of the principles, methodologies, and tools used in the design and development of automotive systems. Emphasis is placed on the integration of various engineering disciplines to design efficient, safe, and innovative vehicles.

Lecturewise Breakup (40 lectures):

I. Introduction to Automotive Design (2 Lectures): Overview of automotive design and its significance, Evolution of automotive design and current trends.

II. Vehicle Dynamics (6 Lectures): Fundamentals of vehicle dynamics: Longitudinal, lateral, and vertical dynamics, Tire mechanics and modeling, Suspension systems: Design and analysis, Steering systems: Types and design considerations, Vehicle stability and control systems.

III. Powertrain Design (8 Lectures): Internal combustion engines: Design and performance, Alternative powertrains: Electric and hybrid systems, Transmission systems: Manual, automatic, and CVT, Drivetrain components and design, Fuel systems and emissions control.

IV. Chassis and Body Engineering (6 Lectures): Design and analysis of vehicle chassis, Body structure and materials, Crashworthiness and impact analysis, Aerodynamics and vehicle design, Noise, vibration, and harshness (NVH) considerations.

V. Automotive Electrical and Electronics Systems (6 Lectures): Electrical system architecture and components, Sensors and actuators in automotive systems, Electronic control units (ECUs) and communication protocols, Infotainment and telematics systems, Advanced driver-assistance systems (ADAS).

VI. Automotive Manufacturing Processes (4 Lectures): Manufacturing techniques for automotive components, Assembly line design and optimization, Quality control and testing procedures, Sustainable manufacturing practices.

VII. Design for Safety and Regulations (4 Lectures): Automotive safety standards and regulations, Design for passive safety: Airbags, seat belts, and crumple zones, Design for active safety: ABS, ESC, and collision avoidance systems, Regulatory compliance and certification processes.

VIII. Ergonomics and Human Factors in Automotive Design (4 Lectures): Principles of ergonomics in vehicle design, Driver and passenger comfort and accessibility, Human-machine interface (HMI) design, Case studies in ergonomic design.

Book References:

1. "Automotive Engineering: Lightweight, Functional, and Novel Materials" by Brian Cantor, P. Grant, and C. Johnston

2. "Fundamentals of Vehicle Dynamics" by Thomas D. Gillespie

3. "The Automotive Chassis: Engineering Principles" by Reimpell, Stoll, and Betzler

4. "Automotive Control Systems: For Engine, Driveline, and Vehicle" by Uwe Kiencke and Lars Nielsen

5. "Vehicle Powertrain Systems" by David Crolla

Toolkit for Managers" by Jeanne Liedtka and Tim Ogilvie

ME MD 1255: Fracture Mechanics

Purpose:

The Fracture Mechanics course aims to provide students with a deep understanding of the principles and applications of fracture mechanics in the analysis and design of engineering structures. This course covers the fundamental concepts, mathematical formulations, and practical techniques necessary for predicting and preventing fracture in materials.

Lecturewise Breakup (40 lectures):

I. Introduction to Fracture Mechanics (2 Lectures): Historical development and significance, Types of fractures: Ductile and brittle fractures, Applications in engineering and material science.

II. Stress Analysis of Cracks (6 Lectures): Stress concentration and stress intensity factor, Modes of crack tip loading: Mode I, Mode II, and Mode III, Westergaard's solutions for stress fields, Crack tip plasticity and Irwin's plastic zone correction, Numerical methods for stress analysis of cracks.

III. Linear Elastic Fracture Mechanics (LEFM) (8 Lectures): Griffith's theory of brittle fracture, Energy release rate and R-curve, Stress intensity factors and fracture toughness, Crack propagation criteria and Paris law, Application of LEFM in design and failure analysis.

IV. Elastic-Plastic Fracture Mechanics (EPFM) (7 Lectures): Concepts of J-integral and crack tip opening displacement (CTOD), Path independence of J-integral, Determination of J-integral and CTOD in laboratory tests, Application of EPFM in materials with significant plasticity, Practical examples and case studies.

V. Dynamic and Time-Dependent Fracture (4 Lectures): Dynamic fracture mechanics: Stress waves and crack propagation speed, Rate effects and dynamic fracture toughness, Creep crack growth and environmental effects on fracture, Fatigue crack growth under cyclic loading.

VI. Fracture in Composite Materials (4 Lectures): Stress analysis in anisotropic materials, Fracture mechanics of fiber-reinforced composites, Delamination and interlaminar fracture toughness, Applications in aerospace and automotive industries.

VII. Fracture Mechanics Testing and Characterization (5 Lectures): Standard fracture toughness tests (ASTM E399, E1820), Compact tension and three-point bending tests, Fatigue crack growth rate testing, Advanced experimental techniques: Digital image correlation (DIC), acoustic emission.

VIII. Numerical Methods in Fracture Mechanics (4 Lectures): Finite element method (FEM) for fracture analysis, Cohesive zone modeling and extended finite element method (XFEM), Applications of numerical methods in predicting fracture behavior.

Book References:

1. "Fracture Mechanics: Fundamentals and Applications" by T. L. Anderson

2. "Fracture Mechanics" by John M. Barsom and Stanley T. Rolfe

3. "Elementary Engineering Fracture Mechanics" by David Broek

4. "Advanced Fracture Mechanics" by M. H. Aliabadi

5. "Fracture Mechanics: An Introduction" by E. E. Gdoutos

ME MD 1261: Mechanical Drives

Purpose:

The course on Mechanical Drives aims to provide students with an in-depth understanding of the principles, design, and analysis of mechanical drive systems used in various engineering applications. This course covers different types of mechanical drives, their components, and performance characteristics, emphasizing practical design considerations and applications.

Lecturewise Breakup (40 lectures):

I. Introduction to Mechanical Drives (2 Lectures): Overview and significance of mechanical drives, Types and applications of mechanical drives (e.g., belt drives, chain drives, gear drives).

II. Belt Drives (8 Lectures): Types of belt drives: Flat belts, V-belts, and synchronous belts, Belt materials and construction, Belt drive geometry and mechanics, Belt tensioning and alignment, Design and selection of belt drives, Performance characteristics and efficiency, Maintenance and troubleshooting of belt drives.

III. Chain Drives (6 Lectures): Types of chain drives: Roller chains, silent chains, Chain materials and construction, Chain drive geometry and mechanics, Design and selection of chain drives, Performance characteristics and efficiency, Maintenance and troubleshooting of chain drives.

IV. Gear Drives (10 Lectures): Types of gears: Spur, helical, bevel, worm, and planetary gears, Gear materials and manufacturing processes, Gear geometry and kinematics, Design and selection of gear drives, Gear ratios and torque transmission, Lubrication and cooling of gear drives, Gear drive performance and efficiency, Noise and vibration in gear drives, Maintenance and troubleshooting of gear drives.

V. Couplings and Clutches (6 Lectures): Types of couplings: Rigid, flexible, and fluid couplings, Coupling materials and construction, Design and selection of couplings, Types of clutches: Friction clutches, electromagnetic clutches, and overrunning clutches, Design and selection of clutches, Performance characteristics and applications.

VI. Shaft Design and Alignment (4 Lectures): Shaft materials and construction, Shaft loading and stress analysis, Shaft alignment techniques and tools, Balancing and vibration analysis of shafts.

VII. Brakes (2 Lectures): Types of brakes: Disc brakes, drum brakes, and electromagnetic brakes, Design and selection of braking systems, Performance characteristics and applications.

VIII. Advanced Topics in Mechanical Drives (2 Lectures): High-speed and high-torque drive systems, Innovations and emerging technologies in mechanical drives.

Book References:

1. "Design of Machinery" by Robert L. Norton

2. "Mechanical Design of Machine Elements and Machines" by Jack A. Collins, Henry R. Busby, and George H. Staab

3. "Machine Elements in Mechanical Design" by Robert L. Mott

4. "Mechanical Engineering Design" by J. E. Shigley and C. R. Mischke

5. "Fundamentals of Machine Component Design" by Robert C. Juvinall and Kurt M. Marshek

<u>ME MD 1262: Machine Tool Design</u>

Purpose:

The course on Machine Tool Design aims to equip students with the knowledge and skills necessary to design and analyze machine tools used in manufacturing processes. Emphasis is placed on the principles of machine tool design, including mechanics, dynamics, thermal effects, and control systems, to enhance the performance, accuracy, and reliability of machine tools.

Lecturewise Breakup (40 lectures):

I. Introduction to Machine Tools (2 Lectures): Overview and significance of machine tools in manufacturing, Types and classifications of machine tools (e.g., lathes, milling machines, grinders).

II. Kinematics of Machine Tools (4 Lectures): Kinematic structure and motion in machine tools, Mechanisms for linear and rotary motion, Kinematic chains and degrees of freedom, Design of feed and speed mechanisms.

III. Mechanics of Metal Cutting (6 Lectures): Fundamentals of metal cutting and chip formation, Cutting forces and power requirements, Tool wear, tool life, and machinability, Design of cutting tools and tool holders, Influence of cutting parameters on tool performance.

IV. Machine Tool Drives (6 Lectures): Types of drives: Mechanical, hydraulic, and electric drives, Design and selection of machine tool spindles, Gearboxes and transmission systems, Servo drives and control systems.

V. Structural Design of Machine Tools (6 Lectures): Materials used in machine tool construction, Design of machine tool structures for stiffness and stability, Analysis of static and dynamic loads, Vibration analysis and damping techniques, Design for thermal stability and heat dissipation.

VI. Precision and Accuracy in Machine Tools (6 Lectures): Factors affecting precision and accuracy in machine tools, Design for geometric and dimensional accuracy, Error analysis and compensation techniques, Metrology and measurement systems for machine tools.

VII. Machine Tool Control Systems (5 Lectures): Control systems in machine tools: Open-loop and closed-loop control, CNC (Computer Numerical Control) systems, PLC (Programmable Logic Controllers) in machine tools, Sensors and feedback devices for control systems.

VIII. Maintenance and Reliability of Machine Tools (5 Lectures): Maintenance strategies: Preventive, predictive, and condition-based maintenance, Reliability analysis and design for reliability, Troubleshooting and diagnostic techniques, Case studies in machine tool maintenance and reliability.

Book References:

1. "Machine Tool Design Handbook" by Central Machine Tool Institute (CMTI)

2. "Principles of Machine Tools" by G.C. Sen and A. Bhattacharya

3. "Metal Cutting Theory and Practice" by David A. Stephenson and John S. Agapiou

4. "Machine Tool Design and Numerical Control" by N.K. Mehta

5. "Design of Machine Elements" by V. B. Bhandari

ME MD 1263: Mechatronics Systems Design

Purpose:

The course on Mechatronics Systems Design aims to provide students with a comprehensive understanding of integrating mechanical, electronic, and computer engineering to design and develop advanced mechatronic systems. The course emphasizes the principles of system integration, sensor and actuator technologies, control systems, and real-time interfacing to create efficient and intelligent mechatronic systems.

Lecturewise Breakup (40 lectures):

I. Introduction to Mechatronics (3 Lectures): Definition and significance of mechatronics, Historical development and applications, Key components and architecture of mechatronic systems

II. Sensors and Actuators (6 Lectures): Types of sensors: position, velocity, acceleration, force, temperature, and others, Working principles and selection criteria for sensors, Types of actuators: electric, hydraulic, pneumatic, Actuator dynamics and selection criteria

III. Signal Conditioning and Data Acquisition (5 Lectures): Analog and digital signal processing, Amplification, filtering, and conversion techniques, Data acquisition systems (DAQ), Interfacing sensors and actuators with DAQ systems

IV. Microcontrollers and Programmable Logic Controllers (PLCs) (6 Lectures): Architecture and operation of microcontrollers, Programming microcontrollers using C/C++, PLC architecture and programming, Applications of microcontrollers and PLCs in mechatronic systems

V. Control Systems in Mechatronics (6 Lectures): Fundamentals of control theory: open-loop and closed-loop systems, PID controllers: design and tuning, State-space representation and control, Digital control systems and real-time control

VI. Modeling and Simulation of Mechatronic Systems (4 Lectures): Mathematical modeling of mechanical, electrical, and hybrid systems, Simulation techniques using MATLAB/Simulink, Case studies on modeling and simulation of mechatronic systems

VII. Real-Time Interfacing and Embedded Systems (5 Lectures): Real-time operating systems (RTOS), Embedded system design and programming, Real-time communication protocols, Case studies on embedded systems in mechatronics

VIII. Mechatronic System Design and Integration (5 Lectures): Design methodology and project planning, System integration techniques, Prototyping and testing, Case studies on the design and integration of mechatronic systems

Book References:

1. "Mechatronics: Principles and Applications" by Godfrey C. Onwubolu

2. "Introduction to Mechatronics and Measurement Systems" by David G. Alciatore and Michael B. Histand

3. "Mechatronics: An Integrated Approach" by Clarence W. de Silva

4. "Microcontroller Theory and Applications with the PIC18F" by M. Rafiquzzaman

5. "Modern Control Engineering" by Katsuhiko Ogata

ME MD 1264: Computational Fluid Dynamics (CFD)

Purpose:

The course on Computational Fluid Dynamics (CFD) aims to provide students with a thorough understanding of the numerical methods and algorithms used to solve fluid flow problems. Emphasis is placed on the theoretical foundation of CFD, its practical applications, and the use of commercial CFD software for solving complex fluid dynamics problems in engineering.

Lecturewise Breakup (40 lectures):

I. Introduction to CFD (3 Lectures): Overview and significance of CFD, Historical development and applications in engineering, Fundamental principles of fluid dynamics and heat transfer

II. Governing Equations of Fluid Dynamics (6 Lectures): Conservation laws: mass, momentum, and energy, Navier-Stokes equations, Simplifications: incompressible flow, potential flow, boundary layer equations

III. Discretization Methods (6 Lectures): Introduction to discretization, Finite difference method (FDM), Finite volume method (FVM), Finite element method (FEM), Comparison of discretization techniques

IV. Grid Generation and Mesh Design (5 Lectures): Structured and unstructured grids, Grid generation techniques, Mesh quality and refinement, Adaptive meshing

V. Numerical Solution of Fluid Flow (6 Lectures): Solution algorithms for linear and nonlinear equations, Explicit and implicit methods, Time-stepping schemes: Euler, Runge-Kutta, Pressure-velocity coupling: SIMPLE, PISO algorithms

VI. Turbulence Modeling (5 Lectures): Introduction to turbulence, Reynolds-averaged Navier-Stokes (RANS) equations, Turbulence models: k-ε, k-ω, LES, DNS, Applications and limitations of turbulence models

VII. Heat Transfer in CFD (4 Lectures): Conduction, convection, and radiation, Coupling of heat transfer and fluid flow, Heat transfer models and boundary conditions, Applications in engineering problems

VIII. CFD Software and Applications (5 Lectures): Introduction to commercial CFD software (e.g., ANSYS Fluent, OpenFOAM), Pre-processing: geometry creation, mesh generation, Solver settings and simulation control, Post-processing: data analysis and visualization

Book References:

1. "Computational Fluid Dynamics: The Basics with Applications" by John D. Anderson

2. "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" by H.K. Versteeg and W. Malalasekera

3. "Computational Fluid Dynamics" by T.J. Chung

4. "Fundamentals of Computational Fluid Dynamics" by Patrick J. Roache

5. "Fluid Mechanics" by Frank M. White

Open Elective Courses:

ME MD 1281: Material Selection in Mechanical Designs

Purpose:

The course on Material Selection in Mechanical Designs aims to provide students with a comprehensive understanding of the principles and methodologies for selecting materials in engineering design. The course emphasizes the relationship between material properties, manufacturing processes, and design requirements to ensure optimal performance, durability, and cost-effectiveness of mechanical components and systems.

Lecturewise Breakup (40 lectures):

I. Introduction to Material Selection (3 Lectures): Importance of material selection in mechanical design**,** Overview of material categories: metals, polymers, ceramics, composites**,** Criteria for material selection: mechanical, thermal, electrical, environmental

II. Material Properties and Performance (6 Lectures): Mechanical properties: strength, hardness, ductility, toughness**,** Thermal properties: thermal conductivity, expansion, resistance**,** Electrical and magnetic properties**,** Environmental resistance: corrosion, oxidation, wear

III. Materials and Manufacturing Processes (6 Lectures): Overview of manufacturing processes: casting, forming, machining, joining**,** Relationship between materials and manufacturing processes**,** Influence of processing on material properties**,** Selection of materials based on manufacturing considerations

IV. Material Selection Methodologies (6 Lectures): Traditional methods: trial and error, experience-based selection**,** Systematic methods: Ashby charts, performance indices**,** Cost-benefit analysis**,** Multi-criteria decision-making techniques

V. Failure Analysis and Material Selection (7 Lectures): Types of failure: fatigue, creep, fracture, wear**,** Failure analysis techniques**,** designing for reliability and durability**,** Selecting materials to prevent failure

VI. Environmental and Sustainability Considerations (6 Lectures): Environmental impact of material production and disposal**,** Sustainable materials and green engineering**,** Life cycle assessment (LCA) in material selection**,** Regulations and standards for environmental compliance

VII. Advanced Materials and Applications (6 Lectures): High-performance materials: superalloys, ceramics, composites**,** Smart materials: shape memory alloys, piezoelectric materials**,** Nanomaterials and their applications**,** Trends and future directions in material science

Book References:

1. "Materials Selection in Mechanical Design" by Michael F. Ashby

2. "Engineering Materials 1: An Introduction to Properties, Applications, and Design" by Michael F. Ashby and David R.H. Jones

3. "Engineering Materials 2: An Introduction to Microstructures, Processing, and Design" by Michael F. Ashby and David R.H. Jones

4. "Materials Science and Engineering: An Introduction" by William D. Callister Jr. and David G. Rethwisch

5. "Materials: Engineering, Science, Processing, and Design" by Michael F. Ashby, Hugh Shercliff, and David Cebon

ME MD 1282: Mechanics of Composite Materials

Purpose:

The course on Mechanics of Composite Materials aims to provide students with a deep understanding of the behavior, analysis, and design of composite materials. Emphasis is placed on the theoretical foundations, material properties, manufacturing processes, and practical applications of composite materials in engineering.

Lecturewise Breakup (40 lectures):

I. Introduction to Composite Materials (3 Lectures): Definition and classification of composite materials**,** Advantages and applications in engineering**,** Overview of matrix and reinforcement materials

II. Constituent Materials (5 Lectures): Matrix materials: polymers, metals, ceramics, Reinforcement materials: fibers, particulates, whiskers, Properties and selection criteria for matrix and reinforcement materials, Interfaces and interphases in composites

III. Micro-Mechanical Analysis (6 Lectures): Micromechanics of a single layer, Volume fraction and density calculations, Rule of mixtures for predicting composite properties, Elastic properties of unidirectional composites

IV. Macro-Mechanical Analysis (6 Lectures): Stress-strain relations for anisotropic materials, Classical lamination theory, Lamina and laminate analysis, Failure theories for composite materials

V. Structural Behavior of Composites (5 Lectures): Bending, buckling, and vibration of composite beams, plates, and shells, Stress analysis of composite structures, Environmental effects: temperature, moisture, fatigue

VI. Damage and Failure in Composites (8 Lectures): Damage mechanisms: matrix cracking, fiber breakage, delamination, Non-destructive testing and evaluation, Failure criteria for composites: maximum stress, maximum strain, Tsai-Wu, Hashin, Damage tolerance and repair techniques

VII. Design and Optimization of Composite Structures (7 Lectures): Design criteria and considerations for composite structures, Optimization techniques for composite materials, Weight and cost considerations, Case studies in aerospace, automotive, and civil engineering

Book References:

1. "Mechanics of Composite Materials" by Robert M. Jones

2. "Principles of Composite Material Mechanics" by Ronald F. Gibson

3. "Composite Materials: Science and Engineering" by Krishan K. Chawla

4. "Engineering Mechanics of Composite Materials" by Isaac M. Daniel and Ori Ishai

5. "Analysis and Performance of Fiber Composites" by Bhagwan D. Agarwal and Lawrence J. Broutman

ME MD 1283: Design of Mechanical Equipment

Purpose:

The course on Design of Mechanical Equipment aims to provide students with the knowledge and skills required to design and analyze various types of mechanical equipment. Emphasis is placed on the principles of mechanical design, detailed design processes, and the creation of engineering drawings for a range of mechanical systems used in different industries.

Lecturewise Breakup (40 lectures):

I. Introduction to Design of Mechanical Equipment (5 Lectures): Overview of mechanical equipment design, Importance and applications in different industries, Design methodologies and processes, Standards and codes in mechanical design, Introduction to CAD software for design and drafting

II. Gear Box Design (5 Lectures): Types and applications of gearboxes, Design of gears: spur, helical, bevel, and worm gears, Load analysis and gear selection, Housing and lubrication design, Engineering drawing and detailing of gearboxes

III. Wind Turbine Rotor Design (5 Lectures): Principles of wind energy conversion, Aerodynamic design of wind turbine blades, Structural analysis and material selection, Mechanical components: hub, shaft, bearings, Detailed drawing and assembly of wind turbine rotor

IV. Wind Turbine Aerodynamic and Mechanical Design (5 Lectures): Aerodynamic performance analysis, Design of mechanical components: gearbox, generator, control systems, Load calculations and safety considerations, Integration of aerodynamic and mechanical designs, Detailed engineering drawings

V. Design of Wind Tunnel (5 Lectures): Types and applications of wind tunnels, Design of test section, contraction cone, diffuser, and drive system, Flow measurement and control systems, Structural and aerodynamic considerations, Detailed engineering drawings of wind tunnel components

VI. Design of Pneumatic and Hydraulic Machines (5 Lectures): Principles of pneumatic and hydraulic systems, Design of actuators, valves, pumps, and cylinders, System integration and control design, Safety and reliability considerations, Detailed engineering drawings of pneumatic and hydraulic machines

VII. Design of Compressors (5 Lectures): Types and applications of rotary and reciprocating compressors**,** Design of compressor components: cylinders, pistons, valves**,** Thermodynamic and mechanical analysis**,** Noise and vibration control**,** Detailed drawing and assembly of a compressor

VIII. Design of Lifting and Earth Moving Machines (5 Lectures): Overview of lifting equipment: cranes, hoists, elevators**,** Design of earth-moving equipment: bulldozers, excavators**,** Load analysis and material selection**,** Structural and mechanical design considerations**,** Detailed engineering drawings of lifting and earth-moving machines

Book References:

1. "Mechanical Design of Machine Elements and Machines" by Jack A. Collins, Henry R. Busby, and George H. Staab

2. "Shigley's Mechanical Engineering Design" by Richard G. Budynas and J. Keith Nisbett

3. "Design of Machinery" by Robert L. Norton

4. "Machine Design: An Integrated Approach" by Robert L. Norton

5. "Mechanical Engineering Design" by J. E. Shigley and C. R. Mischke

Maulana Azad National Institute of Technology Bhopal

Department of Mechanical Engineering

Syllabus of The Lab. Courses for M. Tech in Machine Design

Practical/Laboratory Courses:

ME MD 1104: CAD Analysis and Simulation Lab

Purpose: The CAD Analysis and Simulation Lab is designed for M. Tech Machine Design course students to develop skills in computer-aided design and simulation using advanced software tools. This lab aims to provide students with practical experience in creating, analyzing, and documenting mechanical designs and assemblies, which are essential for modern machine design.

List of Experiments:

1. Introduction to CAD Software: Brief overview of the selected CAD software, Explanation of the user interface and essential tools.

2. Sketching the Component: Basic commands of 2D modeling, Create a 2D sketch of a mechanical component ensuring accurate dimensions and constraints.

3. Creating 3D Components: Basic and advanced commands of 3D solid modeling, Basic and advanced commands of 3D surface modeling.

4. Introduction to Simulation Software: Brief overview of the selected simulation software, Explanation of the user interface and essential tools.

5. Importing the 3D Model from CAD to Simulation Software: Data transfer from CAD to simulation software and their salient features.

6. Setting Up the Simulation: Define the material properties of the component, Apply boundary conditions and external forces/loads, Mesh the model to prepare it for analysis (simple component or assembly analysis).

7. Analyzing the Results: Evaluate the simulation results (stress distribution, deformation, factor of safety), Identify critical areas and suggest possible design improvements.

8. Documentation: Prepare a detailed report documenting the design and simulation process, Include screenshots of the CAD model, simulation setup, and results.

References Book/URLs:

1. "Pro/Engineer PTC Creo Parametric 3.0" by Sham Tickoo

2. "Creo Parametric 3.0 Advanced Tutorial" by Roger Toogood

3. "PTC Creo™ Parametric 3.0" by Louis Gary Lamit

4. [PTC Creo Parametric Online Help (https://support.ptc.com/help/creo/creo_pma/usascii/index.html#page/tutorials_pma/online_help/aux_files/pma_tutorials.html)

ME MD 1105: Experimental Stress Analysis (ESA) Lab

Purpose: The purpose of the Experimental Stress Analysis (ESA) Lab for M. Tech Machine Design course students is to provide hands-on experience in analyzing and measuring stress in mechanical components and structures. The lab focuses on utilizing various experimental techniques to understand stress distribution and deformation, which are critical in the design and analysis of machine components.

List of Experiments:

1. Introduction to the ESA Lab: Familiarization with the lab setup and the fundamental concepts of stress analysis, including the principles of strain and stress measurement.

2. Study of Photoelastic Bench: Understanding the use of photoelasticity as a technique to visualize stress distribution in transparent materials under load.

3. Study of Isoclinics and Isochromatics: Learning to interpret isoclinic and isochromatic fringe patterns, which represent principal stress directions and stress magnitudes, respectively.

4. Determination of Material Fringe Value Using Tensile Test Specimen: Performing tensile tests to determine the material fringe value, a crucial parameter for quantitative photoelastic analysis.

5. Study of Plane Polariscope and Circular Polariscope Arrangements: Exploring the setup and operation of plane and circular polariscopes used in photoelastic experiments to analyze stress patterns

6. Obtaining Isoclinic Pattern in a Circular Disk Under Diametral Compression: Conducting experiments to obtain and analyze isoclinic patterns in a circular disk subjected to diametral compression, illustrating stress distribution.

7. Stress Concentration Factor of Flat Plate with Hole at Center for Tension: Measuring and analyzing stress concentration around a hole in a flat plate under tensile loading, which is critical in design to avoid failure.

8. Calibration of I-Section Specimen in Tension: Calibrating an I-section specimen to determine its stress-strain characteristics under tensile loading conditions

9. Calibration of Beam Under Pure Bending: Analyzing the stress distribution in a beam subjected to pure bending to understand flexural stress and its implications on beam design.

Book References:

1. "Experimental Stress Analysis" by James W. Dally and William F. Riley

2. "Theory of Elasticity" by Timoshenko and Goodier

ME MD 1203: Numerical Simulation Lab

Purpose: The purpose of the Numerical Simulation Lab for M. Tech Machine Design course students is to equip them with the computational skills necessary for solving complex engineering problems. This lab focuses on practical application and mastery of numerical methods using MATLAB.

List of Experiments:

1. Introduction to MATLAB and practice
2. Practice session on handling basic arithmetic, differential, and integral operations etc.
3. Writing codes with control loops, functions and scripts
4. Developing codes for visualization and plotting
5. Solving problems involving linear and nonlinear equations
6. Solving problems involving numerical differentiation and integrations
7. Solving problems involving curve fitting and interpolation
8. Solving problems involving ordinary and partial differential equations
9. Solving Problems related to optimization
10. Case studies on Hyperelasticity, Viscoelasticity, Fatigue and others

Book References:

1. "MATLAB for Engineers" by Holly Moore
2. "Numerical Methods for Engineers" by Steven C. Chapra and Raymond P. Canale
3. "Engineering Optimization: Theory and Practice" by Singiresu S. Rao

ME MD 1204: Mechatronics Lab

Purpose:

The purpose of the Mechatronics Lab for M. Tech Machine Design course students is to provide practical experience in the integration of mechanical, electronic, and computer systems. The lab focuses on pneumatics, electro-pneumatics, and programmable logic controllers (PLCs) to equip students with the skills necessary for designing and troubleshooting automated systems.

List of Experiments:

- **Pneumatics:**

1. Allocating Device: Familiarization with pneumatic systems and designing a basic allocating device using pneumatic components.

2. Sorting Device for Metal Stampings: Development and implementation of a pneumatic sorting device for metal stampings, focusing on control and precision.

3. Vertical Switching Point for Briquettes: Designing and testing a pneumatic system for controlling the vertical switching point in briquette processing.

- **Electro-Pneumatics:**

1. Sorting Device: Design and control of an electro-pneumatic sorting device, integrating sensors and actuators.

2. Opening and Closing Device: Implementation of an electro-pneumatic system for automated opening and closing operations.

3. Turning Device: Development of an electro-pneumatic turning device with precise control mechanisms.

4. Lid Fitting Device: Design and control of a lid fitting device using electro-pneumatic components.

5. Assembly Station: Creation of an electro-pneumatic assembly station to automate part assembly processes.

- **PLC:**

1. Design and Commissioning of a Programmable Logic Controller: Introduction to PLCs, design, and commissioning procedures.

2. Practical Steps for PLC Programming: Hands-on exercises for PLC programming, focusing on fundamental programming techniques.

3. Activating a Cylinder: Hands-on exercise for controlling a cylinder using PLC programming.

4. Bonding of Components: Development of a PLC-controlled system for bonding components in manufacturing.

Book References:

1. "Mechatronics: Principles and Applications" by Godfrey C. Onwubolu

2. "Programmable Logic Controllers" by Frank D. Petruzella

3. "Introduction to Mechatronics and Measurement Systems" by David G. Alciatore and Michael B. Histand