VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE

(VJTI)

MATUNGA, MUMBAI 400 019

(Autonomous Institute affiliated to University of Mumbai)

Curriculum

(Scheme of Instruction & Evaluation and Course contents)

For

Two Year Postgraduate Programme

Leading to Master of Technology

(M Tech) Degree in

Mechanical Engineering with specialization in Machine Design

Implemented from the batch admitted in Academic Year 2022-23

Mechanical Engineering with specialization in Machine Design

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems in the area of Machine Design.

PO2: An ability to write and present a substantial technical report/document in the area of Machine Design.

PO3: Students should be able to demonstrate a degree of mastery in the area of Machine Design. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

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(Central Technological Institute, Maharashtra State, INDIA)
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Curriculum

(Scheme of Instruction & Evaluation and Course contents)

For

Two Year Postgraduate Programme

Leading to Master of Technology

(M Tech)

In

Mechanical Engineering (with Specialization in Machine Design)

M.Tech. in Mechanical Engineering (with specialization in Machine Design)

Scheme of Instruction and Evaluation

SEMESTER I

Scheme of Instruction					**Scheme of Evaluation**			
Sr. No	Course Code	Course Title	L-T-P	Credits	TA	MST	ESE	ESE hours
1.	MEMD5001S	Computational Methods	3-0-0	3	20	20	60	3
2.	MEMD5011T	Mechanical Transmission System Design	3-1-0	4	20	20	60	3
3.	MEMD5012T	Advanced Mechanical Vibration	3-1-0	4	20	20	60	3
4.		Programme elective 1	3-0-0	3	20	20	60	3
5.		Programme elective 2	3-0-0	3	20	20	60	3
6.		Open elective 1	3-0-0	3	20	20	60	3
7.	MEMD5071L	Computational Methods Lab	0-0-2	1	60%CIE		40	-
8.	MEMD5072L	Advanced Mechanical Vibration Lab	0-0-2	1	60%CIE		40	-
9.	MEMD5073L	Mechanism Synthesis Lab	0-0-2	1	60%CIE		40	-
10.		Liberal Learning	0-0-2	1	100%CIE		-	-
			28	24				

abbreviations **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **CIE** Continuous In-semester Evaluation

SEMESTER II

Scheme of Instruction					**Scheme of Evaluation**			
Sr. No	Course Code	Course Title	L-T-P	Credits	TA	MST	ESE	ESE hours
1	MEMD5002S	Research Methodology & IPR	3-0-0	3	20	20	60	3
2	MEMD5013T	Advanced Finite Element Analysis	3-1-0	4	20	20	60	3
3	MEMD5014T	Applied Tribology	3-1-0	4	20	20	60	3
4		Programme elective 3	3-0-0	3	20	20	60	3
5		Programme elective 4	3-0-0	3	20	20	60	3
6		Open elective 2	3-0-0	3	20	20	60	3
7	MEMD5074L	Advanced Finite Element Analysis Laboratory	0-0-2	1	60%CIE		40	-
8	MEMD5075L	Applied Tribology Laboratory	0-0-2	1	60%CIE		40	-
9	MEMD5076L	Additive Manufacturing Laboratory	0-0-2	1	60%CIE		40	-
10		Liberal Learning	0-0-2	1	100%CIE		-	-
			28	24				

abbreviations **L** Lecture, **T** Tutorial, **P** Practical, **TA** Teacher Assessment / Term work Assessment, **MST** Mid Semester Test, **ESE** End Semester Written Examination, **CIE** Continuous In-semester Evaluation

List of Programme Elective 1

Sr. No.	Course Code	Course Title
1	MEMD5021S	Mechanism Synthesis and Dynamics
2	MEMD5022S	System Modeling & Analysis
3	MEMD5023S	Rapid Manufacturing
4	MEMD5024S	Computer Aided Design

List of Programme Elective 2

Sr. No.	Course Code	Course Name
1	MEMD5031S	Stress Analysis
2	MEMD5032S	Experimental Stress Analysis
3	MEMD5033S	IOT Based Condition Monitoring & Diagnostics
4	MEMD5034S	Artificial Intelligence and Machine Learning.

List of Programme Elective 3

Sr. No.	Course Code	Course Name
1	MEMD5041S	Fracture Mechanics
2	MEMD5042S	Fatigue Fracture & Failure Analysis
3	MEMD5043S	Continuum Mechanics

List of Programme Elective 4

Sr. No.	Course Code	Course Name
1	MEMD5051S	Optimization of Engineering Design
2	MEMD5052S	Design of Material Handling Equipment
3	MEMD5053S	Process Equipment Design
4	MEMD5051S	Advanced Composite Materials

SEMESTER III

Scheme of Instruction					Scheme of Evaluation
Sr. No	Course Code	Course Title	L-T-P	Credits	
1.	MEMD5091D	Skill Based Course (Project Stage -I)	---	5	100% CIE
2.	MEMD5092D	Skill Based Course (Project Stage -II)	---	5	100% CIE
3.		Self Learning Course -1	1-0-0	1	100% ESE of 3 hours or credit transfer
4.		Self Learning Course -2	1-0-0	1	100% ESE of 3 hours or credit transfer
5.		Mandatory Non Credit Course	2-0-0	0	100% ESE of 3 hours or credit transfer
				12	

SEMESTER IV

Scheme of Instruction					Scheme of Evaluation
S. No	Course Code	Course Title	L-T-P	Credits	
1.	MEMD5093D	Skill Based Course (Project Stage -III)	---	5	100% CIE
2.	MEMD5094D	Skill Based Course (Project Stage -IV)	---	7	100% CIE
				12	

SEMESTER-I

Programme Name	***Masters of Technology in Mechanical Engineering with Specialization in Machine Design***
Course Code	**MEMD5001S**
Course Title	**Computational Methods**

Course Outcomes

After completion of course, students would be able to

1. Solve algebraic equations, Eigen value problems
2. Analyze data using interpolation and regression methods.
3. Solve ordinary and partial differential equations using numerical techniques

Course Contents

Introduction

Engineering problems and computational methods; Introduction to numerical methods and analysis.

Error Analysis

Approximations; Round-off and Truncation errors; Backward and Forward error analysis

Roots of Nonlinear Equations

Bisection method, Regula Falsi, Secant method, Fixed point Method; Newton-Raphson method; Multiple roots; Roots of system of non-linear equations; Analysis and order of convergence; Polynomials Mueller's method, Bairstow's method**.**

Solution of System of Linear Equations

Direct methods (Gauss Elimination, Gauss-Jordan, LU decomposition, Thomas Algorithm); Perturbation analyses of direct methods matrix and vector norms, condition number of matrix; Iterative methods (Jacobi and Gauss-Seidel); convergence criteria for Jacobi and Gauss Seidel iterative methods, rate of convergence of iterative methods. Successive over Relaxation.

Solution of System of Nonlinear Equations

Iterative methods, Fixed Point iteration, Newton-Raphson method.

Approximation of functions

Approximation using polynomials (Simple, least squares estimation, orthogonal basis functions, Tchebycheff and Legendre polynomials); Interpolation (Newton's divided difference and Lagrange interpolating polynomials, Spline interpolation); Regression

Eigen values and Eigen vectors

Power, inverse power, and inverse power method with shift, Fadeev-Leverrier method for the formulation of the Characteristic polynomials and QR decomposition

Numerical Differentiation

Introduction to finite difference approximations, Derivation of generalized finite difference approximation of any order and accuracy, truncation error analysis, Richardson's extrapolation

Numerical Integration

Newton-Cotes integration formula, Romberg integration and Gauss Legendre quadrature; Ordinary

Ordinary Differential Equations (Initial Value Problems)

Euler's method, Multi-step methods, Runge-Kutta methods, Predictor Corrector Methods. Stiff ODEs. System of IVPs, Stiff problems and Gear's method

Ordinary Differential Equations (Boundary Value Problems)
Decomposition into Linear System of ODEs, Shooting and direct methods;
Partial Differential Equations Introduction to solution of PDEs, Parabolic (diffusion equation and advective-diffusion equation), Elliptic (Laplace equation) and Hyperbolic (Wave equation) equations; Explicit and Implicit Methods, Crank Nicholson Method

Recommended Reading

1. Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers, McGraw Hill
2. Santosh Gupta, Numerical Methods for Engineers, New age international publishers
3. J.B. Doshi, Differential Equations for Scientists and Engineers, Narosa, 2010
4. Kreyszig, Erwin, I.S., Advanced Engineering Mathematics, Wiley, 1999
5. C. F. Gerald and P.O. Wheatley, Applied Numerical Analysis, Pearson Education Asia, New Delhi, Sixth Edition, 2006.

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5011T**
Course Title	**Mechanical Transmission System Design**

Course Outcomes:

At the end of the semester the student should be able to:

1. Select the appropriate transmission system by making comparative analysis
2. Design or select various components of Mechanical Power transmission system.
3. Justify the use of hydraulic and Pneumatic system.

Course Contents: -

Introduction to Power transmission devices
Comparison, selection criteria, characteristics, Limitations, applications.

Mechanical Power transmission systems
Design/ selection of various mechanical drives viz. Gears, Belts clutches, chains etc., Use of various standards, Analysis of the solution further with respect to vibration, wear, life of critical components, reliability, assembly, maintenance and cost.

Hydraulic Transmission systems
Introduction to fluid Power and Physical Properties. applications of Pascal's law, conservation of energy, hydraulic power, Bernoulli's equation, laminar and turbulent flow, Hydraulic pumps, Hydraulic Motors. Hydraulic cylinders. Hydraulic cylinders operating features, cylinder velocity and power, cylinder designs, Hydraulic Valves, Hydraulic Circuit Design and Analysis, Hydraulic oils; Desirable properties, general type of fluids, sealing devices, reservoir system, filters and strainers

Pneumatic Transmission systems
Choice of working medium, characteristics of compressed air. Structure of Pneumatic control system, Pneumatic Actuators, Design parameters, selection, ISO symbols, Valves: Design and constructional aspects, poppet valves, slide valves spool valve, suspended seat type slide valve, Pressure dependent controls, Time dependent controls Electro-Pneumatic control, Compressed air: Production of compressed air – compressors, preparation of compressed air- Driers, Filters, Regulators, Lubricators, Distribution of compressed air- Piping layout.

Reference:

1. Vicker's Manual
2. Industrial Hydraulic – Rhoner, 3rd Ed, 1994, John Wiley & Sons
3. Industrial Hydraulic – John Pippenger, 3rd Ed, 1979, McGraw Hill Publications
4. Fundamentals of Pneumatics – Festo
5. Fluid power applications – A.Esposito, 7th Ed, 2013, Pearson Education
6. Industrial Fluid Power – Andrew Parr, Butterworth-Heinemann; 2 edition (March 22, 1999)
7. Gear Design Handbook – Gitin Maitra, Tata McGraw-Hill Education, 1994
8. Design of machine elements – M F Spotts, Prentice Hall; 8 Edition (October 24, 2003)
9. Design of Machine elements – V M Faires, 4th Ed, 1965, MacMilan Co.

Programme Name	***Masters of Technology in Mechanical Engineering with Specialization in Machine Design***
Course Code	**MEMD5012T**
Course Title	**Advanced Mechanical Vibration**

Course Outcomes:

At the end of the semester the student should be able to:

1. Analyse the causes and effects of vibrations in mechanical systems and identify discrete and continuous systems.
2. Model the physical systems into schematic models and formulate the governing equations of motion.
3. Compute the free and forced vibration responses of multi degree of freedom systems and understand the quality of the results.
4. Analyse and design systems involving transmissibility, vibration isolation and absorption.
5. Analyse and design to control and reduce vibration effects in machinery.

Course Contents

Introduction

Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, Linearization of nonlinear systems, Physical models, Schematic models and Mathematical models, Fourier Transform and its usefulness to vibration analysis.

Single Degree of Freedom (SDF) systems

Formulation of equation of motion: Newton – Euler method, De Alembert's method, Energy method, Free Vibration: Undamped Free vibration response, Damped Free vibration response, Coulomb and Hysteresis damping, Forced vibration response of SDF systems: Response to harmonic excitations, solution of differential equation of motion, Magnification factor, Resonance, Rotating/reciprocating unbalances. Vibration under general force conditions for a single degree of freedom system.

Two Degree of Freedom Systems

Introduction, Formulation of equation of motion: Equilibrium method, Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Forced vibration response, Analysis of vibration absorbers.

Multi Degree of Freedom Systems

Introduction, Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, Orthogonality of modal vectors, Normalization of modal vectors, Decoupling of modes, Modal analysis, Rayleigh's damping.

Continuous Systems:

Introduction to continuous systems, discrete vs continuous systems, Free vibrations of bar and shaft, Free vibrations of beam, Approximate methods for continuous systems and introduction to Finite element method.

Vibration Control

Reduction of vibration at the source, Vibration control: passive & active control and semi active control, Damping, Vibration isolation, Vibration absorbers. Introduction to permissible vibration limits as per API/ISO.

Vibration Measurement

Vibration measuring instruments: Transducers, Pickup, Frequency measuring Instruments, Vibration exciters/shakers, Signal analysis, Experimental modal analysis, Machine condition monitoring.

Introduction to non-linear vibration

Recommended Reading:

1. Singiresu S. Rao, Mechanical Vibrations. 4th Ed., Pearson education, 2011.
2. W.T, Thompson, Theory of Vibration, CBS Publishers & Distributors, 3rd Edition, 1988.
3. S. Graham Kelly, Fundamentals of Mechanical vibration, McGraw Hill Book Company, 2000.
4. L. Meirovich, Elements of Vibration Analysis, 2nd Ed. Tata McGraw Hill Book Company, 2007.
5. P. Srinivasan, Non-Linear Mechanical Vibrations, John Wiley, 1995.

Programme Elective-I

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5021S**
Course Title	**Mechanism Synthesis and Dynamics**

Course Outcomes:

At the end of the semester the student should be able to:

1. Develop analytical equations describing the position, velocity and acceleration of all moving links.
2. Synthesize mechanical components into complete systems.
3. Solve real life problems using vector mechanics.

Course Contents:

Module 1

Basic Concepts: Definitions and assumptions; planar and spatial mechanisms; kinematic pairs; degree of freedom; equivalent mechanisms; Kinematic Analysis of Planar Mechanisms. Review of graphical and analytical methods of velocity and acceleration analysis of kinematically simple mechanisms, velocity-acceleration, analysis of complex mechanisms by the normal acceleration and auxiliary-point methods.

Module 2

Curvature Theory: Fixed and moving centrodes, inflection circle, Euler-Savary equation, Bobillier constructions, cubic of stationary curvature, Ball's point, Applications in dwell mechanisms.

Module 3

Kinematic Analysis of Spatial Mechanisms, Denavit-Hartenberg parameters, matrix method of analysis of spatial mechanisms.

Module 4

First and Second time derivatives of a vector fixed in moving reference frame – velocity and acceleration of a point on rigid body – moving on rigid body. Relationship of time derivatives of vector for different reference frames, Coriolis force.

Module 5

Definition of inertia quantities, Translation of coordinate axes, transformation properties of inertia terms, Tensor notations of transformation, Ellipsoid of inertia, Principal moment of inertia.

Module 6

Angular momentum and its time derivative for a particle and system of particles. Euler's Equation of motion, Applications of Euler's equation, Fixed point rotation.

Recommended Reading:

1. R.S. Hartenberg and J. Denavit, Kinematic Synthesis of Linkages, McGraw-Hill, New York, 1980.
2. Robert L.Nortan ,Design of Machinery', Tata McGraw Hill Edition .
3. Hamilton H.Mabie,Mechanisms and Dynamics of Machinery, John Wiley and sons New York.
4. S.B.Tuttle, Mechanisms for Engineering Design John Wiley and sons New York
5. A. Ghosh and A.K. Mallik, Theory of Machines and Mechanisms, Affiliated East-West Press, New Delhi, 1988.
6. A.G. Erdman and G.N. Sandor, Mechanism Design – Analysis and Synthesis, (Vol. 1 and 2), Prentice Hall India, 1988.
7. A.S. Hall, Kinematics and Linkage Design, Prentice Hall of India.
8. J.E. Shigley and J.J. Uicker, Theory of Machines and Mechanisms, 2nd Edition, McGraw-Hill, 1995.
9. I H Shames & G. Krishna Mohan Rao, Engineering Mechanics Statics & Dynamics, 4th Ed, Pearson Publication.
10. Thomas Kane , Dynamics – Theory and Applications, , 1 st Ed. McGraw Hill Book Company.

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5022S**
Course Title	**System Modeling & Analysis**

Course Outcomes:

At the end of the semester the student should be able to:

1. Develop mathematical model for various types of systems.
2. Use transfer function and state space approach for finding solutions.
3. Calculate transient and steady state response for various input conditions.

Course Contents

Mechanical systems

Mathematical modeling of mechanical elements – inertia, stiffness and damper and mathematical modeling of mechanical systems – vehicles, articulated vehicle and other mechanical systems.

Electrical systems and Electro-mechanical systems.

Fundamentals of Electrical Circuits, Mathematical Modeling of Electrical Systems, Mathematical Modeling of Electromechanical Systems

Fluid Systems and Thermal Systems

Mathematical modeling of hydraulic elements and system – Pneumatic elements and system.

Transfer function and state space approach

Transfer function representation, block diagram, State variable representation, matrix equation. Solution of state equation. Equivalent state space model.

Time and Frequency domain analysis

Transient response of First and Second order system, Steady state response, Step Response, Ramp response, Impulse response, Sinusoidal response, Convolution integral, Stability and controllability of system.

Recommended Reading

1. Dynamics System Modelling& Analysis – Hung V Vu & R. S. Esfandi
2. K. Ogata, System Dynamics, Pearson Education India; 4th edition 2014
3. I.J. Nagarath & M.Gopal, Control System Engineering, New age international publication, 5th Edition.
4. K. Ogata, Modern Control Engineering, Prentice Hall, 5th edition

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5023S**
Course Title	**Rapid Manufacturing**

Course Outcomes:

At the end of the semester the student should be able to:

1. To understand and evaluate various existing Product Development processes
2. To develop new technologies in the field Rapid Prototyping & Manufacturing
3. To generate innovative ideas to reduce time and cost by developing new methods and materials for the modern manufacturing industry.

Course Contents:

Introduction:

Product Developing Cycle, Definition of Rapid Product Development, Virtual prototypical and rapid manufacturing technologies, Physical Prototyping & rapid manufacturing technologies, Synergic integration technologies.

Rapid Prototyping Processes:

Principal of Rapid Prototyping (RP), Various RP technologies, Selection of a suitable RP process for a given application, Status of outstanding issues in RP- accuracy, speed, materials (strength, homogeneity and isotropy), Emerging Trends. Applications and Case Studies: Engineering Applications, Medical Applications.

Computer Numerical Control:

Fundamentals of CNC machine tools, Programming of CNC machines, Tool path generation, Direct Numerical Control. Automatically Programmed Tool (APT).

Rapid Tooling:

Introduction to Rapid Tooling, Indirect Rapid Tooling Processes, Direct Rapid Tooling Processes, Emerging Trends in Rapid Tooling.

Reverse Engineering:

Need for Reverse Engineering, Digitizing Methods and its Principles, Types measurements, Contact & Non-contact Types, Coordinate Measuring Machine (CMM), Capture devices, Sensors, Scanning Methods, 3D scanners, Data representation, Data processing and manipulation techniques. Applications .

Rapid Manufacturing Processes:

Definition of Rapid Manufacturing, Roadmap to Rapid Manufacturing, Comparison of Various Processes for Rapid Manufacturing of Metallic Objects, Rapid Manufacturing of Polymeric Objects, Rapid Casting, other RM Processes like Hybrid Layered Manufacturing, Material Translation, Segmented Object Manufacturing.

Processing of Polyhedral Data:

Processing of Polyhedral Data: Polyhedral BRep modeling, Introduction to STL format, Defects and repair of STL files, Overview of the algorithms required for RP&T and Reverse Engineering

Recommended Reading

1. Rapid Prototyping: Principles and Applications in Manufacturing, Chua Chee Kai and Leong Kah Fai, John Wiley & Sons, 1997.
2. Rapid Product Development & Manufacturing, by K.P.Karunakaran, IIT, Bombay, 1st edition, 2013.
3. Rapid Tooling: Technologies and Industrial Applications by Peter D. Hilton and Paul F. Jacobs (Editors.), Marcel Dekker. 4th edition, 2000
4. Rapid Prototyping Principles and Applications by RafiqNoorani, John Wiley & Sons -1st edition, 2006.
5. Garage Virtual Reality by Linda Jacobson, Sams Publishing, 1994.
6. User's Guide to Rapid Prototyping, By Todd Grimm, Society of Manufacturing Engineers, 1st edition, 2004.
7. Stereo-lithography and Other RP&M Technologies: from Rapid Prototyping to Rapid Tooling by Paul F. Jacobs, SME/ASME, 1996.
8. Rapid Manufacturing , An Industrial Revolution for the digital age by N. Hopkinson, R. J. M. Hague -2nd edition, 2006.
9. Virtual Reality Systems by John Vince, Addison-Wesley. 1995.
10. Virtual Reality by Ken Pimentel, Kevin Teixeira, Windcrest McGraw-Hill, 1st edition, 2003.
11. Rapid Prototyping by Andreas Gebharatdt, Hanser Publishers, 2nd edition – 2003.

Programme Name	Master of Technology in Mechanical Engineering with specialization in Machine Design
Course Code	**MEMD5024S**
Course Title	**Computer Aided Design**

Course Outcomes

At the end of the semester the student should be able to:

1. Generate the geometric entities such as lines, circle using scan conversion algorithms
2. Perform 2D/3D transformations of geometric objects
3. Analyse the curves and surfaces using in CAD
4. Use techniques of AI in CAD
5. Understand use of virtual reality in CAD

Course Contents

Introduction: Introduction to CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Scan Conversion, Geometric modelling.

Transformations in Geometric Modelling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations

Representation of Curves: Analytic Curves, Composite Ferguson curves, Hermite Cubic Splines, curve Trimming and Blending, Bernstein polynomials, Bezier Curves, Bezier-subdivision, Degree elevation, Composite Bezier, Splines, B-spline basis functions, Properties of basic functions, Knot Vectors, NURBS

Representation of Surfaces: Parametric representation, Planer, Sweep surfaces, Surface of revolution, Bi-linear, lofted, Coon‘s patch, Hermite, Bezier, B-Spline surfaces, Developable surfaces, Surfaces of revolution, Intersection of surfaces, Surface modelling,

Design of Solids: Solid entities, Boolean operations, B-rep of Solid Modelling, CSG approach of solid modelling, Data exchange formats, Geometric Modeling using Point Clouds, Reverse Engineering

Feature Based Modeling: Feature recognition, types of features, feature recognition schemes, feature recognition methods, Artificial Intelligence for feature recognition.

Introduction to Virtual Reality: Definition of VR, Features of VR, Real time Response, Optimization of the Rendering Process, Technologies used in VR, Stereo Displays, Interactions in VR, Tracking based interaction, Data Generation for VR, Haptic Rendering, Applications of VR, Simulation in VR, Augmented Reality AR, Introduction to VR softwares.

Recommended Reading:

1. Mathematical Elements for Computer graphics Rogers & Adams Tata McGraw –Hill, New Delhi, 2nd Edition, 2002
2. Geometric Modeling, Michael E. Mortenson, Tata McGraw Hill, 2013.

3. Computer-Aided Engineering Design, Saxena and B. Sahay, AnamayaPublishers, New Delhi, 2005
4. CAD/ CAM , Theory & Practice. by Ibrahim Zeid, R. Sivasubramanian, Tata McGraw Hill Publications, 5th edition, 2009
5. Principles of CAD/CAM/CAE systems, Kunwoo Lee, Addison-Wesley (1999)
6. Paul Mealy, Virtual & Augmented Reality for Dummies, John Wiley & Sons.

Programme Elective-II

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5031S**
Course Title	**Stress Analysis**

Course Outcomes

The student should be able to

1. Identify advanced techniques available for characterization of materials.
2. Select a characterization technique to evaluate the behavior of materials
3. Analyze defects and failure surfaces of materials
4. Analyze the characterization results by various equipment

Course Contents

Introduction

Overview of the course; materials classification and their properties, Importance of materials selection, property classification, Criteria for selection of materials, Ashby charts for materials selection, Engineering Design process and the role of materials; material property charts; selection of materials based on function, objective, constraints and free variables; examples of material selection for typical applications.

Computer aided materials selection

Selection of process based on material classification; pencil curve approach; material selection for multiple constraints and multiple objective cases; multiple constraints and conflicting objectives. Co-selection of material and shape; concept of macroscopic and microscopic shape factors; Four quadrant method of material selection. General Properties of plastics, polymers and elastomers; visco-elastic properties; short-term and long-term properties of plastics.

High temperature materials

Families of super alloys and their characteristics; creep and fatigue resistance of super alloys; role of precipitates in strengthening of super alloys; repair of super alloys after creep damage; coatings for high temperature materials.

Fundamentals of ceramics

General properties, applications of ceramics for critical applications. Design considerations. Surface treatment of materials using coatings; type of coatings; PVD and CVD coatings. Basics of electro-plating and electro-less plating.

Physical characterization of materials

Optical Microscopy, SEM,TEM, Density, Void content in materials, Electron Probe Micro Analyzer (EPMA), Atomic Force Microscopy (AFM), Thermogravimetric analysis (TGA), nano indentation, NMR spectroscopy, EDAX, FTIR, XRD.

Mechanical characterization

Tensile test, flexural test, compression test, ILSS, creep, fatigue, Hardness, Impact test, Fracture toughness test, Principle, construction and operation working parameters, equipment operation. selection of plastics based on mechanical properties, degradation due to environment, of laminates.

Recommended Reading

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 4th Edition, 2010
2. Yang Leng, Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd, 2008
3. ASM Handbook Materials Characterization, ASM International, 2008.
4. V. T. Cherapin and A. K. Mallik, Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
5. Dieter, George E., Mechanical Metallurgy, McGraw Hill, 2nd Edition, 2005
6. Crawford, R. J., Plastics Engineering, Butterworth-Heinemann, 3rd Edition, 2002.
7. Donachie, M. J. and Donachie, S. J., Super alloys A technical guide, ASM International, 2002.

Programme Name	*Master of Technology in Mechanical Engineering with specialization in Machine Design*
Course Code	**MEMD5032S**
Course Title	**Experimental Stress Analysis**

Course Outcomes

At the end of the semester the student should be able to:

1. The various experimental techniques involved for measuring displacements and stresses
2. Stress and strain measurements in loaded components.
3. The usage of strain gauges and photo elastic techniques of measurement.
4. The strain analysis of measuring circuits.
5. The Different types of coatings.

Course Contents

Photo Elasticity

Arrangement of optical elements in a polar scope , Theory of photo elasticity, Plane & circular polariscope, Isoclinics and isochromatics. Model Materials: Properties, selection and method of calibration. Different methods of analysis: Compensation technique, principle stresses separation technique, calibration methods fringe Multiplication, scaling model to prototype, Application of photo elasticity for two dimensional models. Three Dimensional Photo elasticity :Stress locking in model materials ,slicing technique, shear difference method. Scattered light photo elasticity. Dynamic photo elasticity.

Strain Gauges

Electrical Resistance strain gauges: types, gauge factor, sensitivity, applications. Materials, Bonding of strain gauges: surface preparation, moisture proofing etc. types of bonds, Testing of gauge installations. Strain measuring circuits, commercial strain indicators. Rosette Analysis. Strain gauge transducers. Cross sensitivity, Temperature compensation. Semi –Conductor strain gauges.

Coating Methods for stress analysis

Coating stresses, Birefringent coatings (Photoelastic &Brittle coatings), coating sensitivity, coating materials, analysis of brittle- coating data.

Holography

Equation for plane waves and spherical waves Intensity – Coherence – Spherical radiator as an object (record process) Hurter – Driffeld curve reconstruction process General case. Holographic set up.

Moire technique

Geometrical approach – sensitivity of Moire data - data reduction in plane and out plane Moire methods – Moire photography – Moire grid production. Introduction to idea of radio telemetry for measurement of stress/strain.

Recommended Reading

1. Dally and Riley, Experimental Stress Analysis. McGraw Hill.

2. Srinath, Lingaiah, Raghavan, Gargesa, Ramachandra and Pant, Experimental Stress Analysis. Tata McGraw Hill.
3. Sadhu Singh Experimental Stress Analysis. Hanna publisher.
4. Hand Book of Experimental Stress Analysis by Hyteneyi.
5. Hand Book of Experimental Stress Analysis. by A. S. Kobayassin (Ed), SEM/VCH, II edition.
6. Abdul Mubeen, Experimental Stress Analysis, Dhanpat Rai & Co (P) Ltd.
7. U. C. Jindal, Experimental Stress Analysis , Pearson India Publishers.

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5033S**
Course Title	**IOT Based Condition Monitoring & Diagnostics**

Course Outcomes:

At the end of the semester the student should be able to:

1. Demonstrate fundamentals of artificial intelligence and machine learning.
2. Apply feature extraction and selection techniques.
3. Apply machine learning algorithms for classification and regression problems.
4. Devise and develop a machine learning model using various steps.
5. Explain concepts of reinforced and deep learning.

Course Contents

Introduction to Artificial Intelligence and Machine

History of AI, Comparison of AI with Data Science, Need of AI in Mechanical Engineering, Introduction to Machine Learning. Basics: Reasoning, problem solving, Knowledge representation, Planning, Learning, Perception, Motion and manipulation. Approaches to AI: Cybernetics and brain simulation, Symbolic, Sub-symbolic, Statistical. Approaches to ML: Supervised learning, Unsupervised learning, Reinforcement learning.

Feature Extraction and Selection

Feature selection: Ranking, Decision tree - Entropy reduction and information gain, Exhaustive, best first, Greedy forward & backward, Applications of feature extraction and selection algorithms in Mechanical Engineering. Feature extraction: Statistical features, Principal Component Analysis

Classification and Regression

Classification: Decision tree, Random Forest, Naive Bayes, Support vector machine. Regression: Logistic Regression, Support Vector Regression. Regression trees: Decision tree, random forest, K- Means, K-Nearest Neighbor (KNN). Applications of classification and regression algorithms in Mechanical Engineering.

Development of ML Model

Problem identification: classification, clustering, regression, ranking. Steps in ML modeling, Data Collection, Data pre-processing, Model Selection, Model training (Training, Testing, K-fold Cross Validation), Model evaluation (understanding and interpretation of confusion matrix, Accuracy, Precision, Recall, True positive, false positive etc.), Hyper parameter Tuning, Predictions.

Reinforced Learning

Characteristic of reinforced learning, Algorithms: Value Based, Policy Based, Model Based; Positive vs Negative Reinforced Learning; Models: Markov Decision Process, Q Learning. Application of Reinforced Learning in Mechanical Engineering.

Deep Learning

Characteristic of Deep Learning, Artificial Neural Network, Convolution Neural Network, Application of Deep Learning in Mechanical Engineering.

Recommended Reading

1. Deisenroth, Faisal, Ong, Mathematics for Machine Learning, Cambridge University Press, 2020.
2. B Joshi, Machine Learning and Artificial Intelligence, Springer, 2020.
3. Parag Kulkarni and Prachi Joshi, Artificial Intelligence – Building Intelligent Systems, PHI learningPvt. Ltd., ISBN – 978-81-203-5046-5, 2015.
4. Stuart Russell and Peter Norvig (1995), Artificial Intelligence: A Modern Approach, Third edition,Pearson, 2003.
5. Solanki, Kumar, Nayyar, Emerging Trends and Applications of Machine Learning, IGI Global, 2018.
6. Mohri, Rostamizdeh, Talwalkar, Foundations of Machine Learning, MIT Press, 2018.
7. Kumar, Zindani, Davim, Artificial Intelligence in Mechanical and Industrial Engineering, CRC Press,2021.
8. Zsolt Nagy - Artificial Intelligence and Machine Learning Fundamentals-Apress (2018).
9. Artificial Intelligence by Elaine Rich, Kevin Knight and Nair, TMH.

Laboratory Courses

Programme Name	***Masters of Technology in Mechanical Engineering with Specialization in Machine Design***
Course Code	**MEMD5071L**
Course Title	**Laboratory-1 Computational Methods Laboratory**

Course Outcomes

After completion of course, students would be able to

1. Write codes that use computational methods to numerically solve problems in a variety of disciplines in Mechanical Engineering.
2. Learn open source packages that implement popular computational methods.
3. Apply the mathematical concepts the Computational Methods course.

Course Contents

The lab will involve development of programs based on numerical methods using Python/Matlab/Scilab etc. for solving variety of common Mechanical Engineering problems.

1. Program for solving system of linear equations
2. Program for regression analysis and curve / function fitting to a given data set
3. Program for root finding on non-linear equation
4. Program for Numerical Differentiation and Integration
5. Program for solving differential equations based on Runge-Kutta formulation
6. Program for Boundary Value Problems in Ordinary and Partial Differential Equations

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5072L**
Course Title	**Laboratory-2 Advanced Mechanical Vibration Lab**

Course Outcomes:

At the end of the semester the student should be able to:

1. Write computer programme using MATLAB or other programming language for studying beats, calculating natural frequencies, etc.
2. Perform dynamic force analysis of a mechanism

List of Experiments/Assignments

Any five experiments/assignments from the following shall be conducted.

1. Study of beats using computer code using MATLAB code.
2. Dynamics force analysis of any 4 or higher bar Mechanism.
3. Natural frequencies and mode shapes of multiple degree of freedom problem using ANSYS.
4. Calculation of natural frequencies of continuous system using MATLAB code and ANSYS.
5. Computer implementation of Holzer matrix method using MATLAB code.
6. Computer implantation of a suitable numerical method using MATLAB e.g. mode superposition method, etc.
7. Experimental analysis of –
   a. Unbalanced rotor,
   b. Bent shaft,
   c. Faulty bearing,
   d. Misalignments etc. using Machinery Fault simulator.
   Study of vibration characteristics of bearings and gears be included in the study.
8. Seminar / Case studies.

Programme Name	Master of Technology in Mechanical Engineering with specialization in Machine Design
Course Code	**MEMD5073L**
Course Title	**Laboratory-3 Mechanism Synthesis Lab**

Course Outcomes:

At the end of the semester the student should be able to:

1. Develop analytical equations describing the position, velocity and acceleration of all moving links.
2. Synthesize mechanical components into complete systems.
3. Solve real life problems using vector mechanics.

List of Experiments/Assignments

1. Analysis of any 4-bar mechanism using analytical method and software tool.
2. Develop a computer code for analysis of 4 bar mechanism.
3. Synthesis of any mechanism having minimum 6 links –
   a. Selection of Mechanism.
   b. Modeling using suitable software.

Kinematic and dynamic analysis for various inputs.

SEMESTER-II

Programme Name	*Master of Technology in Mechanical Engineering with specialization in Machine Design*
Course Code	**MEMD5002S**
Course Title	**Research Methodology and IPR**

Course Outcomes

After completion of course, students would be able to

1. Understand research problem formulation and approaches of investigation of solutions for research problems.
2. Learn ethical practices to be followed in research and apply research methodology in case studies and acquire skills required for presentation of research outcomes
3. Discover importance of Intellectual Property Rights.
4. Promote Intellectual Property Right and patenting.

Course Contents

Research Problem

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Literature Review

Effective literature studies approaches, analysis, Plagiarism, Research ethics,

Technical Writing

Effective technical writing, how to write report, Paper, Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Nature of Intellectual Property

Patents, Designs, Trade and Copyright. Process of Patenting and Development technological research, innovation, patenting, development. International Scenario International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Patent Rights

Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

New Developments in IPR

Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies.

Recommended Reading

1. Ranjit Kumar, Research Methodology A Step by Step Guide for beginners, 2nd Edition
2. C.R. Kothari, Research Methodology Methods and Techniques
3. Halbert, Resisting Intellectual Property, Taylor & Francis Ltd., 2007.
4. Mayall, Industrial Design, McGraw Hill, 1992.
5. Niebel, Product Design, McGraw Hill, 1974.
6. T. Ramappa, Intellectual Property Rights under WTO, S. Chand, 2008

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5013T**
Course Title	**Advanced Finite Element Analysis**

Course Outcomes

At the end of the semester the student should be able to:

1. Formulate numerical model for a given system.
2. Obtain numerical Solutions for boundary value problems.
3. Solve mechanical engineering problems using Finite Element Methods.

Course Contents

Introduction to Finite Element Analysis

Introduction, Basic concept of Finite Element analysis, Discretization of continuum, Stiffness Matrix and Boundary Conditions, Introduction to elasticity, Plane Stress and Plain strain Problem

Finite Element Formulation Techniques

Virtual Work and variational principle, Variational Formulation of Boundary Value problem, Variational Method such as Ritz and weighted Residual methods. Galerkin Method Potential Energy Approach, Displacement Approach

Element Properties

Natural coordinates, Triangular Elements, Rectangular Elements, Lagrange and Serendipity Elements, Solid Elements, Isoparametric Formulation, Stiffness Matrix for Isoparametric Elements, Numerical Integration

Displacement Models

Convergence requirements, Shape functions, Element stresses and strains, Strain-Displacement Matrix for Bar Element, Strain Displacement Matrix for CST Element, Strain Displacement Relation for Beam Element

Analysis of Frame Structure

Introduction of Truss Members, Stiffness of Beam Members, Finite Elements analysis of Beams

FEM for Two Dimensional Solids

Constant and Linear Stain Triangle, Rectangular Elements, Finite Element Formulation for 2D elements. Axisymmetric Elements. Finite Element Formulation of Axisymmetric Elements Heat Transfer by conduction and convection for one dimensional and two-dimensional elements

FEM for Three Dimensional Solids

Tetrahedral elements, Pentahedral (Wedge) elements, Hexahedral (Brick) elements

Error Analysis and Convergence of Finite element Solution

Introduction of error analysis, A Posteriori Error analysis, Super convergent Patch theory.

Dynamic Analysis Using FEA

Introduction, Vibration Problems, Free vibration and normal modes, The mode superposition method, Equation of motion Based on weak form and Lagrange’s Approach, Consistent and Lumped mass Matrices, Properties and Solution of Eigen Value Problems, Transient Vibration Analysis.

Recommended Reading

1. Finite Elemenet Analysis By S.S. Bhavikatti, New Age International Publication.
2. Introduction to FEM by Desai and Abel
3. The Finite Element Method for Solid and Structural Mechanics –Zienkiewicz & Taylor, Elsevier Publications
4. Finite Element Analysis by J.N. Reddy, McGraw Hill Book Co.
5. Finite Element Method in Engineering by S.S.Rao, Pergamon Press
6. Textbook on Finite Element Analysis by P. Seshu, Prentise Hall Publications
7. Finite Element Analysis by Bathe and Wilson
8. Introduction to Finite Element Analysis by T. *Chandrupatla* and A. D. Belegundu, Prentice Hall
9. Finite Element Modeling For Stress Analysis for Robert D.Cook , John Wiley & Sons.
10.Computational Elasticity by Mohammad Ameen, Narosa Publishing House.

Programme Elective-III

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5041S**
Course Title	**Fracture Mechanics**

Course Outcomes

At the end of the semester the student should be able to:

1. Apply the concept of stress intensity factor, energy release rate, J integral, Crack tip opening displacement in a given situation.
2. Analyse the plastic zone at the crack tip.
3. Analyse the role of fatigue and estimate fatigue crack propagation life of a component with a crack in it.
4. Learn sophisticated experimental techniques to determine fracture toughness and stress intensity factor.

Course Contents

Introduction
Background, Kinds of failure, modes of failure, brittle and ductile fracture.

Energy Consideration
Introduction, Griffith analysis, energy release rate.

Stress in Cracked Bodies
Stress intensity factor, Stress and displacement fields, Determination of SIF

Elastic Plastic Fracture Mechanics
J integral- Definition, scope, path independence, CTOD.

Test methods
Introduction, K_{IC} test technique, J testing, Various test specimens.

Fatigue
Introduction, terminology, S-N curve, fractures due to fatigue, Effect of overload, Variable Amplitude Fatigue Load, Paris law for design of components.

Recommended Reading

1. Kumar, Prashant, Elements of Fracture mechanics, McGraw-Hill Education Pvt. Limited, New Delhi, 2009
2. Maiti, Surjya Kumar, Fracture Mechanics: Fundamentals and Applications, Cambridge University Press, Delhi, 2015
3. Broek, David, Elementary Engineering Fracture Mechanics, Maritinus Nijhoff Publishers, 1982
4. Anderson, Ted L. Fracture mechanics: fundamentals and applications. CRC press, 2005.
5. Gdoutos, E.E. (2005). Fracture Mechanics - An Introduction, Springer, Dordrecht, (2005).
6. Ramesh, K. . Engineering fracture mechanics, NPTEL
7. Baker, Fracture Mechanics, Mc Graw Hill
8. Handbook of Stress Intensity Factors, Tada, Sih & Paris, ASM.

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5042S**
Course Title	**Fatigue Fracture & Failure Analysis**

Course Outcomes

At the end of the semester the student should be able to:

1. Understand the role of fatigue damage in design consideration and estimate fatigue crack propagation life of a component with a crack in it.
2. Understand the concept of damage tolerance and essentials of fracture parameters.
3. Appreciate the characteristics of the types of a fracture and be able to analyse a given mechanical failure of material.

Course Content

Fatigue

Fatigue crack propagation: Fatigue crack growth theories, crack closure, Microscopic theories of fatigue crack growth.

Fracture

Microscopic theories of fracture: Ductile and cleavage fracture, ductile-brittle transition, inter-granular fracture.

Linear Elastic Fracture Mechanics

Griffith's theory of brittle failures; Irwin's stress intensity factors; Linear elastic fracture mechanics: The stress analysis of crack tips, Macroscopic theories in crack extension, Instability and R-curves, Crack tip plasticity, K as a failure criterion, Mixed mode of fracture,

Determination of SIF

Analytical and Experimental methods of determining K;

Elastic Plastic Fracture Mechanics

Crack tip opening displacement, J Integrals, Crack growth resistance curves, Crack tip constraint under large scale yielding,

Applications

Application of theories of fracture mechanics in design and materials development.

Recommended Reading

1. Dieter, George E., Physical Metallurgy, McGraw Hill Education, 3rd Edition, 2017.
2. Kumar, Prashant, Elements of Fracture mechanics, McGraw-Hill Education Pvt. Limited, New Delhi, 2009.
3. Maiti, Surjya Kumar, Fracture Mechanics: Fundamentals and Applications, Cambridge University Press, Delhi, 2015.
4. Broek, David, Elementary Engineering Fracture Mechanics, Maritinus Nijhoff Publishers, 1982

5. Anderson, Ted L. Fracture mechanics: fundamentals and applications. CRC press, 2005.

Programme Name	*Master of Technology in Mechanical Engineering with specialization in Machine Design*
Course Code	**MEMD5043S**
Course Title	**Continuum Mechanics**

Course Outcomes

At the end of the semester the student should be able to:

1. Be familiar with linear vector spaces relevant to continuum mechanics and able to perform vector and tensor manipulations in Cartesian and curvilinear coordinate systems.
2. Formulate and solve specific technical problems of displacement, strain and stress
3. Numerically model and analyse the stresses and deformations of simple geometries under an arbitrary load in both solids and liquids
4. Be able to derive equations of motion and conservation laws for a continuum.

Course Contents

Introduction

Introduction to Continuum Mechanics

Mathematical Preliminaries: Vectors and Tensors

Vector Algebra, Index notation, Tensors and tensor operations, Vector and tensor operations in polar coordinates, Transformation Law for Different Bases, Summation Convention, Dummy index, Free index. Kronecker delta, Transformation laws for orthonormal systems, Theory of Matrices, Vector Calculus, The Del Operator, Divergence and Curl of a Vector, Cylindrical and Spherical Coordinate Systems.
Gradient, Divergence, and Curl Theorems Dyads and Dyadics, Nonion Form of a Second-Order Tensor, Transformation of Components of a Tensor, Tensor Calculus. Eigenvalues and Eigenvectors, Eigenvalue problem, Eigenvalues and eigenvectors of a real symmetric tensor, Calculation of eigenvalues and eigenvectors.

Kinematics – Mathematical Description of Motion and Deformation

Introduction, Descriptions of Motion, Configurations of a Continuous Medium,
Material Description, Spatial Description, Displacement Field, Analysis of Deformation, Deformation Gradient , Isochoric, Homogeneous, and Inhomogeneous Deformations ,Isochoric deformation , Homogeneous deformation , nonhomogeneous deformation, Change of Volume and Surface ,Volume change , Area change , Strain Measures ,Cauchy–Green Deformation Tensors , Green–Lagrange Strain Tensor Physical Interpretation of Green–Lagrange Strain Components Cauchy and Euler Strain Tensors, Transformation of Strain Components, Invariants and Principal Values of Strains, Infinitesimal Strain Tensor and Rotation Tensor, Infinitesimal Strain Tensor, Physical Interpretation of Infinitesimal Strain Tensor Components, Infinitesimal Rotation Tensor, Infinitesimal Strains in Cylindrical and Spherical Coordinate Systems. Cylindrical coordinate system, Spherical coordinate system, Velocity Gradient and Vorticity Tensors, Definitions, Relationship Between D and E, Compatibility Equations, Preliminary Comments, Infinitesimal Strains, Finite Strains, Rigid-Body Motions and Material Objectivity Superposed Rigid-Body Motions, Introduction and rigid-body transformation, Material Objectivity. Observer transformation, Objectivity of various kinematic measures, Time rate of change in a rotating frame of reference, Polar Decomposition Theorem. Preliminary Comments Rotation and Stretch Tensors, Objectivity of Stretch Tensors.

Stress Measures

Introduction, Cauchy Stress Tensor and Cauchy's Formula ,Stress Vector, Cauchy's Formula ,Cauchy Stress Tensor , Transformation of Stress Components and Principal Stresses ,Transformation of Stress Components , Invariants ,Transformation equations , Principal Stresses and Principal Planes ,Maximum Shear Stress , Other Stress Measures , Preliminary Comments , First Piola–Kirchhoff Stress Tensor ,Second Piola–Kirchhoff Stress Tensor , Equilibrium Equations for Small Deformations , Objectivity of Stress Tensors , Cauchy Stress Tensor , First Piola–Kirchhoff Stress Tensor , Second Piola–Kirchhoff Stress Tensor.

Conservation and Balance Laws

Introduction, Conservation of Mass, Preliminary Discussion, Material Time Derivative, Vector and Integral Identities. Vector identities, Integral identities, Continuity Equation in the Spatial Description. Continuity Equation in the Material Description, Reynolds Transport Theorem. Balance of Linear and Angular Momentum,

Principle of Balance of Linear Momentum, Equations of motion in the spatial description, Equations of motion in the material description. Spatial Equations of Motion in Cylindrical and Spherical Coordinates, Cylindrical coordinates, Spherical coordinates. Principle of Balance of Angular Momentum, Thermodynamic Principles, Balance of Energy, Energy equation in the spatial description, Energy equation in the material description.

Constitutive Equation

Introduction, General Principles of Constitutive Theory, Elastic Materials, Cauchy-Elastic Materials, Green-Elastic or Hyper Elastic Materials, Linearized Hyper Elastic Materials, Infinitesimal Strains General Principles of Constitutive Theory Material Frame Indifference, Elastic Materials Cauchy-Elastic Materials. Green-Elastic or Hyper Elastic Materials, Linearized Hyper Elastic Materials: Infinitesimal Strains, Hookean Solids, Generalized Hooke's Law, Material Symmetry Planes,

Monoclinic Materials, Orthotropic Materials, Isotropic Materials Nonlinear Elastic Constitutive Relations Newtonian Fluids. Ideal Fluids. Viscous Incompressible Fluids, Generalized Newtonian Fluids, Viscoelastic Constitutive Models.

Linearized Elasticity

Introduction, Governing Equations, Preliminary Comments, Summary of Equations

Strain-displacement equations , Equations of motion, Constitutive equations, Boundary conditions Compatibility conditions , The Navier Equations , The Beltrami–Michell Equations , Solution Methods , Types of Problems ,Types of Solution Methods .Stretching and Bending of Beams ,Superposition Principle , Uniqueness of Solutions ,Clapeyron's, Betti's, and Maxwell's Theorems, Clapeyron's Theorem, Betti's Reciprocity Theorem , Maxwell's Reciprocity Theorem, Solution of Two-Dimensional Problems Introduction , Plane Strain Problems Plane Stress Problems . , Unification of Plane Stress and Plane Strain Problems ,Airy Stress Function, Saint-Venant's Principle, Torsion of Cylindrical Members ,Warping function, Prandtl's stress function, Methods Based on Total Potential Energy , The Variational Operator,The Principle of the Minimum Total Potential Energy, Construction of the total potential energy functional, Euler's equations and natural boundary conditions. Minimum property of the total potential energy functional, Castigliano's Theorem, The Ritz Method, The Variational problem, Description of the method, Hamilton's Principle. Hamilton's Principle for a Rigid Body, Hamilton's Principle for a Continuum

Linearized Viscoelasticity

Initial Value Problem, the Unit Impulse, and the Unit Step, Function. The Laplace Transform Method. Spring and Dashpot Models, Creep Compliance and Relaxation Modulus, Maxwell Element. Creep response, Relaxation response, Kelvin–Voigt Element, Creep response. Relaxation response, Three-Element Models, Four-Element Models Integral Constitutive Equations., Hereditary Integrals, Hereditary Integrals for Deviatoric Components, The Correspondence Principle, Elastic and Viscoelastic Analogies.

Recommended Reading

1. Introduction to Continuum Mechanics,, W. Michael Lai, David Rubin and Erhard Kremp, Butterworth-Heinemann publication, Fourth Edition • 2010
2. Continuum Mechanics Modeling of Material Behavior, Martin Sadd, Elsevier Academic Press,1st Edition,2018.
3. An introduction to continuum mechanics: with applications, J.N.Reddy Second Edition, Cambridge University Press, 2008.

Programme Elective-IV

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5051S**
Course Title	**Optimization of Engineering Design**

Course Outcomes

At the end of the semester the student should be able to:

1. Understand the basics of statistical tools for certainty analysis.
2. Asses various design of experiment techniques and suggest a suitable technique for a situation.
3. Understand a situation and apply the robust design strategy to it.

Course Contents

Uncertainty, Statistical Tools and Techniques of handling Uncertainty.

The Mystique of Probability, Idea of a Random Variable, `Hypothesis Testing', Comparing Two Population, Cause-Effect Models and Regression ,Cause Factor, F-Statistic , The Mean Sum of Squares

Design Process.

Re-engineering, Reverse Engineering of Design, Concurrent Engineering

Design Of Experiment.

One-Factor Designed Experiment, ANOVA Helps Compare Variability, Factor Effects are Statistically Significant, Sum of Squares and the F-Test

Taguchi Method

Design Achieving Quality—Taguchi's Seven Points Optimized Design, Reduces R&D, Production, and Lifetime Cost. Taguchi's Definition of Quality, Causes Performance, Prevention by Quality Design Steps in Designing Performance into a Product Functional Design, Parametric Design, Additivity, the Response table,

Signal to Noise Ratio

Selecting Factors for Taguchi Experiments Seek Robustness One Should Measure Performance by S/N Ratios, S/N Ratio in Optimization, OA as the Experiment Matrix, Axiomatic Approach to Design

Orthogonal Arrays

Orthogonal Arrays, Control and Noise Factors: The Ishikawa Diagram, Optimized Design, Testing for Additivity, The Optimization Strategy, Taguchi's Two Steps to On-Target Performance with Minimum Variability Programme

Process/ Product Optimization.

Passive Network filter, Formal Statement of the Design Problem, Robust Design Formulation of the Problem, Data Analysis and Estimation of Effects, Effects of the Design Parameters, The

Process for Manufacturing Optical Filters, Control Parameters and the OA Performance Measurements and the S/N Ratio Minimizing log10 (s2), Variability of Thickness.

Robust Design

Re-Statement of the Multiple Objective Design Optimization, Target Performance Requirements as Explicit Constraints, Constraints Present in the Filter Design, Seeking Pareto-Optimal Design, Monte Carlo Evaluation of S/N Ratios, Necessary Mathematical Tools, Developing a Multiple Regression Model, Rationale of the Constrained Robust Design Approach, Application of the Constrained Approach to Real, Discussion of the Constrained Design Optimization

Loss function and Design Tolerances.

Loss to Society is More Than Defective Goods, Determining Manufacturing Tolerances, Loss Functions for Mass-Produced Items.

Recommended Reading

1. Tapan P. Bagchi; Taguchi Method Explained, PHI, New Delhi, 1sted, 1993
2. Suh Nam P.; the Principles of Design, Oxford university Press, NY, 1sted, 1990
3. Hammer Michel, Champy J. ; Re-engineering the Corporation, Nicholas Brealey publishing, London.

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5052S**
Course Title	**Design of Material Handling Equipment**

Course Outcomes

At the end of the semester the student should be able to:

1. Design sub systems of Electrically operated overhead travel Crane.
2. Design various components of single stage radial flow centrifugal pump for given specification.
3. Design various components External Gear Pump for given conditions.
4. Design sub-systems of flat belt conveyor for field application.

Course Contents

Cranes

Classification, Criteria for selection. Types of cranes and their Layouts. Design of Electrically operated overhead travel Crane: Snatch block Assembly, Hoisting Mechanism, Traveling Mechanism – Trolley and Bridge. Design of Bridge Girder: Box type, Truss type.

Single Stage Radial Flow Centrifugal Pump

Motor selection, Suction and delivery pipe, Impeller, Impeller shaft with bearing, Casing Geometry.

External Gear Pump

Classification, Working Principle, Construction. Design of External Gear Pump: Motor selection, Gears, Gear shaft, Bearings, Cover and casing. Bolts, Pipe selection.

Belt Conveyor

Classification, Merits and Demerits. Design of Belt Conveyor: Belt, Roller Assembly, Drum & Drum Shaft, Bearings. Motor selection. Take-up arrangements.

Recommended Reading

1. K Sahu, Pumps: Theory, Design and Applications, 1st Ed, New age Publication 2000
2. Dr Jagdish Lal, Hydraulic Machines, Metropolitan Book Co Pvt Ltd,
3. Spivakosky & Dyachkov , Conveying Machines, , Mir Publication Moscow, 1985
4. Indian Standards: - IS: 807, IS: 3443, IS: 3777, IS: 3815, IS: 3973
5. Vicker's Manual
6. K. Mahadevan, Recommended Data Books- PSG,
7. Alexandrov, Material handling Equipments, MIR Publication. Moscow
8. S.N. Trikha, Machine Design Exercises, , Khanna Publications, Delhi
9. N. Rudenko, Material handling Equipments, , Peace Publication

Programme Name	Master of Technology in Mechanical Engineering with specialization in Machine Design
Course Code	**MEMD5053S**
Course Title	**Process Equipment Design**

Course Outcomes

At the end of the semester the student should be able to:

1. Discuss the aspects of design, flowsheets and scaleup in process plant design.
2. Design pressure vessels by selecting a suitable material of construction and ASME code.
3. Design Heat exchangers and evaporators.
4. Design of different supports and column.

Course Content

Type of vessels and factors influencing the design of vessels. Classification of vessels such as tank, flat, bottomed and vertical cylinder tank, vertical cylindrical and horizontal vessels with formed ends as well as spherical or modified spherical vessels.

Criteria in vessel design. Elastic bending, plastic instability, cyclic loading stress reversals. Brittle rupture and creep rupture corrosion.

Design of simple vessels of different configuration. General proportions and lay-out. Vents, tapping and flanges.

Design of tall vertical vessels and supports

Elementary heat exchanger design.

Recommended Reading

1. Pressure vessels design and practice, By: SomnathChattopadhyay. Publication: CRC Press. Ed: 2005
2. Overview of pressure vessel design, By: Vincent A. Carucci. Publication: ASMEInternational
3. Process equipment design, By: Brownell and Young. Publication: Wiley Eastern Limited. Ed:1959, sixth reprint Sept 1991.
4. Review of code for pressure vessels, IS 2825 as compared to ASME/BS/ADMerkblatter, By: N K Roy. Publication: Journal for Process Equipment & Piping Technology. Vol 1, No 1, June 1994
5. A special report : Worldwide pressure vessel codes. Publication: Hydrocarbon
6. Processing, Dec 1978.
7. ASME Section VIII Div-1, 2 & 3 Ed. 2010 Addenda 2011a.
8. Theory & Design of Pressure Vessels, By: John F Harvey, 15th Edition, Van Nostrand Reinhold Company Ltd.
9. Pressure Vessel Design Handbook By H. Bedner
10. Pressure Vessel Design Manual – Dennis Moss

Programme Name	Masters of Technology in Mechanical Engineering with Specialisation in Machine Design
Course Code	**MEMD5054S**
Course Title	**Advanced Composite Materials**

Course Outcomes

At the end of the semester the student should be able to:

1. Identify the properties of fiber and matrix materials used in composites.
2. Select an appropriate manufacturing process for composite parts.
3. Analyse the performance of fiber composites based on the constituent properties.
4. Model the behaviour of composite materials
5. Understand nanocomposites processing and properties

Course Contents

Introduction to Composites

Introduction to material selection in design, Types of composite materials, general characteristics of composite materials, applications of composites

Constituents of Composite

Materials Reinforcement and fillers: glass fibers, carbon fibers, organic fibers, boron fibers, natural fibers, ceramic fibers Matrix: thermoset matrix and thermoplastic matrix, metal matrix materials, ceramic matrix materials

Manufacturing of Composites

Bag-molding, compression molding, pultrusion, filament winding, liquid composite molding, resin film infusion, additive manufacturing of short fiber and long fiber composites, metal matrix composite manufacturing, ceramic matrix composite manufacturing, selection of manufacturing method

Mechanics of Fiber Reinforced Composite Materials

Fiber matrix interaction, micromechanics of composite materials, Laminate Analysis, Failure theories for composite materials, introduction to world-wide failure exercise of composites

Characterization of Fiber Reinforced Composite Materials

Static mechanical properties, fatigue properties, impact properties, methods of characterization of fiber-matrix interphase, quality inspection methods, different ASTM standards

Fracture and Fatigue of Fiber Reinforced Composite Materials

Failure of composites, delamination in composites, modes of fracture, composite damage mechanics, S-N diagram for composite materials

Polymeric Nanocomposite

Introduction to nanomaterials, nanoplatelete/nanoparticles/nanofibers reinforced composites, CNT/Graphene reinforced composites, processing of nanocomposites, prediction of properties of nanocomposites, applications of nanocomposites

Modeling of Composite Materials

Empirical models for prediction of mechanical properties of composites, finite element based modelling of short fiber and long fiber composites, Introduction to ANSYS ACP module for composite analysis, Simulation of short fiber reinforced composites using Digimat

Recommended Reading

1. P.K. Mallick, Fiber-Reinforced Composites: Materials, Manufacturing, and Design, Third Edition, CRC Press, 2007.
2. K. K. Chawla, Composite Materials: Science and Engineering, Springer, 2012
3. Ever Barbero, Finite Element Analysis of Composite Materials using ANSYS, CRC Press, 2013.
4. Hussain, Farzana, et al., Review article: polymer-matrix nanocomposites, processing, manufacturing, and application: an overview. Journal of composite materials 40.17, 2006: 1511-1575.
5. M. Ashby, Material Selection in Mechanical Design, 4th Edition, Elsevier, 2010.

Laboratory Courses

Programme Name	***Masters of Technology in Mechanical Engineering with Specialization in Machine Design***
Course Code	**MEMD5074L**
Course Title	**Laboratory-4 Advanced Finite Element Analysis Laboratory**

Course Outcomes:

1. To acquire basic understanding of Modeling and Analysis software ·
2. Be able to use the commercial Finite Element packages to build and solve selected problems.
3. To understand the different kinds of static analysis, find out the stress and other related parameters.
4. To learn to apply the basic principles to carry out dynamic analysis.

List of Experiments/Assignments

1. 1-D Element Problems –Linear Static Analysis
2. 2-D Element Problems – Linear Static Analysis
3. 3-D Element Problems – Linear Static Analysis
4. Free Vibration Analysis on Beam, Bars, Plates
5. Non-Linear Analysis of 1-D Element Problems Like Beams, Bars
   Thermal Analysis(Conduction, Convection and Insulation Boundary Conditions.
6. 1-D Element Problems-Steady state And Transient Analysis
7. 2-D Element Problems of Homogeneous and Composite Slap in Steady State and Transient Analysis
8. 3-D Element Problems Steady State Analysis
9. Project-Creating or Importing and Map Meshing of 3-D component /Assembly of practical application and FEA Analysis of Same component /Assembly

Reference Material:

1. Finite Element Analysis using Ansys 11.0 by PaletiShrinivas, Krisha Chaitnay Sambana, Rajesh Kumar Datti.
2. Finite Element Analysis Theory and Applications with ANSYS by Saeed Moaveni
3. Engineering Analysis with ANSYS Software by Y. Nakasone and S. Yoshimoto
4. The finite element method And applications in Engineering using Ansys® by Erdogan Madenci, Ibrahim Guven
5. Practical Finite Element Analysis by Nitin Gokhale of M/S Finite to Infinite.
6. Reference Manual of Hypermesh Software
7. Online Tutorial HyperMesh Software
8. Tutorial of Ansys Software.

Programme Name	Master of Technology in Mechanical Engineering with specialization in Machine Design
Course Code	**MEMD5075L**
Course Title	**Laboratory-5 Additive Manufacturing Laboratory**

Course Outcomes

At the end of the semester the student should be able to:
1. To process 'STL' files from 3D models
2. To build rapid prototyping parts using FDM process
3. To apply surface finish enhancement techniques on FDM parts.
4. To develop CNC part programmes.

List of Experiments:

1. Development of 3D CAD models and Assemblies using CAD Software to generate STL files.
2. Processing of STL files of 3D modelled parts/assemblies
3. Building Rapid Prototyping (FDM) parts/assemblies
4. Applying post processing techniques on FDM parts
5. Surface roughness measurement of FDM parts.
6. Tool path generation using CAM software : Introduction to 'CAM' software, Importing and modifying 3D geometry, Selecting tools, Generating operation, specific tool path, Generating G-codes and M-codes in 'CAM' software
7. CNC part programming on CNC machine: Introduction to existing CNC machine in the lab, Introduction and details of its corresponding control software, Machining parts, as per given drawings.
8. Using Coordinate Measuring Machine: Demonstration on existing CMM machine, Introduction and details of controlling software, Measuring various components.

Programme Name	***Master of Technology in Mechanical Engineering with specialization in Machine Design***
Course Code	**MEMD5076L**
Course Title	**Laboratory Advanced Composite Materials Laboratory**

Course Outcomes

After completion of the course students will be able to

1. Develop composite manufacturing process for the given part
2. Evaluate the performance of composite structure
3. Design the optimal composite structure

List of experiments

1. Resin Preparation and cure cycle
2. Manufacture of composite material using hand layup process
3. Manufacture of natural fibers composite materials
4. Open mold composite manufacturing process
5. Vacuum assisted resin transfer molding process
6. Manufacture of sandwich composite
7. Testing of polymeric composite materials
8. Finite element analysis of composite materials
9. Design optimization of composite structure
10. Manufacture of electrospun nanofibers reinforced composites

Text Books

1. P.K. Mallick, Fiber-Reinforced Composites Materials, Manufacturing, and Design, CRC Press, Third Edition, 2007
2. ANSYS Composite PrepPost User's Guide, http//www.ansys.com