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# *Scheme of Instruction*

## *and*

## *Syllabus of*

## Ph.D. (MECHANICAL ENGINEERING)

**With effect from AY 2025-2026**

**OSMANIA UNIVERSITY**

**HYDERABAD–500007**

**TELANGANA.**

# RESEARCH METHODOLOGY IN MECHANICAL ENGINEERING

**Code: PHD6001ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives:**

1. Understand the fundamentals of research methodology and scientific research in Mechanical Engineering.
2. Develop the ability to identify research problems through literature review and research tools.
3. Learn to design experiments and apply appropriate methods for data collection and analysis.
4. Develop skills in technical writing, research ethics, publication, and proposal preparation.
5. Introduce modern research techniques, numerical methods, simulation, and machine learning applications in Mechanical Engineering.

**Course Outcomes:** After completion of the course student will be able to

**CO1:** Identify and formulate research problems through critical literature review.
**CO2:** Design research methodologies and experimental plans for engineering research.
**CO3:** Analyze and interpret research data using statistical and computational methods.
**CO4:** Prepare research reports, technical papers, theses, and research proposals following ethical practices.
**CO5:** Apply advanced experimental, numerical, simulation, and machine learning techniques to solve Mechanical Engineering research problems.

**UNIT – I**

**Research Methodology:** Objectives and Motivation of Research, Types of Research, Research Approaches, Significance of Research, Research Methods verses Methodology, Research and Scientific Method, Importance of Research Methodology, Research Process, Criteria of Good Research, Problems Encountered by Researchers in India, Benefits to the society in general. **Defining the Research Problem:** Definition of Research Problem, Problem Formulation, Necessity of Defining the Problem, Technique involved in Defining a Problem.

**Literature Survey**: Importance of Literature review, Sources of Information, Assessment of Quality of Journals and Articles, critical appraisal of Literature Review, arriving final problem definition

**UNIT – II**

**Research Design:** Meaning of Research Design, Need for Research Design, Important Concepts Related to Research Design, Different Research Designs, Basic Principles of

Experimental Design, Developing a Research Plan, Design of Experimental Setup, Use of Standards and Codes.

**Research Tools:** Methods to Search Required Information Effectively, Citation Styles, Reference Management Software (Zotero / Mendeley / EndNote).

**Plagiarism:** Plagiarism and Self-Plagiarism, Consequences of Plagiarism, Unintentional Plagiarism, Copyright Infringement, Software for Detection of Plagiarism (Turnitin / iThenticate).

**UNIT – III**

**Data Collection:** Data Types, Collection of Primary Data, Secondary Data, Data Organization, Data Validation, Methods of Data Grouping, Diagrammatic Representation of Data, Graphical Representation of Data, Sample Design and Population.

**Data Analysis:** Mathematical Modeling — Definition of Model, Types of Models, Mathematical Models and Modeling of Engineering Systems. Probability and Its Distribution, Hypothesis Testing, Tests for Significance: Chi-Square, Student's t-Test, Regression Modeling, ANOVA, F-Test, Time Series Analysis. Role of Statistics in Data Analysis.

**UNIT – IV**

**Research Report Writing:** Format of the Research Report, Preparation of Synopsis in an Effective Manner, Thesis Writing, Arrangement of Chapters and Finalization of Chapter Names. Ethics and Moral Issues Related to Research and Publishing. References / Bibliography.

**Technical Paper Writing:** Layout of a Research Paper, Impact Factor of Journals, Research Indicators (Citations / h-index / i10-index / Cite Score, etc.), Research Profile Building (ORCID iD / Google Scholar iD / PubMed / Scopus iD, etc.).

**Research Proposal Preparation**

Funding agencies in India and across the globe, writing research proposals, writing research grant proposals: Minor and Major Research Proposals (UGC, ANRF, AICTE etc.,).

**UNIT–V**

**Advancements and Research Scope in Mechanical Engineering**

**Experimental Methods:** Measuring instruments: Strain, stress, force, torque, pressure, fluid flow, Temperature and their calibration methods, characterization techniques: optical microscope, SEM, AFM.

**Numerical Methods:** Introduction to - Finite Difference Methods, Finite Element Methods and Finite Volume Methods.

**Machine Learning Techniques:** Introduction to Supervised and Unsupervised Learning, Reinforcement Learning, Simulation Tools.

**Suggested Readings:**

1. C. R. Kothari, *Research Methodology: Methods and Techniques*, New Age International Publishers, 2004.

2. R. Ganesan, *Research Methodology for Engineers*, MJP Publishers, 2011.

3. Vijay Upagade and Arvind Shende, *Research Methodology*, S. Chand & Company Ltd., New Delhi, 2009.

4. P. Ramdass and Wilson Aruni, *Research and Writing Across the Disciplines*, MJP Publishers, Chennai, 2009.

5. Margaret Cargill and Patrick O'Connor, *Writing Scientific Research Articles: Strategy and Steps*, John Wiley & Sons Ltd., 2009.

6. *MLA Handbook for Writers of Research Papers*, The Modern Language Association of America, New York, 2009.

7. Holman, J.P.: Experimental Methods for Engineers, 8th Edition, McGraw Hill Int., New York, 2012.

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## FINITE ELEMENT TECHNIQUES

**Code: PHD6002ME**

***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours***

***SEE: 100 marks*** | ***Credits: 3***

**Course Objectives:**

1. Understand the fundamentals of the Finite Element Method (FEM) and its formulation for engineering problems.
2. Develop the ability to formulate and analyze one-, two-, and three-dimensional engineering problems using finite element techniques.
3. Learn to apply FEM for structural, thermal, dynamic, and fluid flow analyses.
4. Gain knowledge of numerical solution techniques and finite element modelling procedures.
5. Familiarize with the use of finite element software for solving practical Mechanical Engineering problems.

**Course outcomes:** After completion of the course student will be able to

**CO1:** Explain the basic concepts, formulation, and principles of the Finite Element Method.

**CO2:** Formulate and solve one- and two-dimensional structural problems using appropriate finite elements.

**CO3:** Analyze heat transfer and dynamic engineering problems using finite element techniques.

**CO4:** Apply finite element methods to three-dimensional stress analysis and fluid flow problems.

**CO5:** Use finite element software to model and solve practical Mechanical Engineering problems.

**UNIT-I**

Introduction: Historical Background, General description of the finite element method, Mathematical Modeling of field problems in Engineering, Governing Equations, Discrete and continuous models, Boundary, Initial and Eigen Value problems, Weighted Residual Methods, Variational Formulation of Boundary Value Problems, Potential energy method, Rayleigh Ritz method, Galerkin's method of finite element formulation. Strain displacement relations, Stress strain relations, Interpolation models: Simplex, complex and multiplex elements, Linear interpolation polynomials in terms of local, natural and global coordinates for 1D, 2D, 3D Simplex Elements. Finite element equations, treatment of boundary conditions.

**UNIT-II**

One-Dimensional Elements-Analysis of Bars and Trusses, Linear interpolation polynomials in terms of local coordinate's for 1D, 2Delements. Higher order interpolation functions for 1D quadratic and cubic elements in natural coordinates, Analysis of plane truss with number of unknowns not exceeding two at each node. Analysis of frames with two translations and a

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rotational degree of freedom at each node. Analysis of Beams: Element stiffness matrix for two noded, two degrees of freedom per node for beam element. Torsion of Shafts: Finite element formulation of shafts, determination of stress and twists in circular shafts.

**UNIT-III**

Finite element modeling of two-dimensional stress analysis problems with constant strain triangles and treatment of boundary conditions. Two dimensional four noded iso-parametric elements and numerical integration. Plane stress, plane strain and axi-symmetric problems, Body forces and temperature effects. Stress calculations, Plate and shell elements. Elements. Convergence requirements and geometric isotropy. Application to Field Problems, Thermal problems, Analysis of a uniform shaft subjected to torsion using Finite Element Analysis. Quadrilateral elements and Higher Order Elements.

**UNIT-IV**

Steady state heat transfer analysis: One dimensional analysis of a fin, composite walls and two-dimensional conduction analysis of thin plate. Time dependent field problems: Application to one dimensional heat flow in a rod. Dynamic analysis: Formulation of finite element modeling of Eigen value problem for a stepped bar and beam. Evaluation of Eigen values and Eigen vectors.

**UNIT-V**

Finite element formulation of three-dimensional problems in stress analysis. Fluid Flow: Flow through a porous medium, Flow through pipes of uniform and stepped sections, Flow through hydraulic networks. Finite Element formulation of an incompressible fluid. Potential flow problems Bending of elastic plates. Introduction to non-linear problems and Finite Element analysis software.

**Suggested Readings:**

1. Tirupathi R Chandraputla and Ashok. D. Belegundu, Introduction of Finite Element In Engineering", Third Edition, Prentice Hall of India, 2002.
2. Rao S.S., "The Finite Element Methods in Engineering", Fifth Edition, Pergamon Press, 2010.
3. Segerland. L.J., "Applied Finite Element Analysis", Second Edition, Wiley Publication,1984.
4. Reddy J.N., "An Introduction to Finite Element Methods", Fourth Edition, Mc Graw Hill Company,2020.
5. P.Seshu, "Text book of Finite Element Analysis", Tenth Edition, PHI Learning Pvt. Ltd., 2012.

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## THEORY OF METAL FORMING

**Code: PHD6003ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

Course Objectives

1. Understand the fundamentals of metal forming processes and the principles of plastic deformation.
2. Develop knowledge of sheet metal forming, bulk metal forming, and powder metallurgy processes.
3. Learn to analyze forming processes, estimate process parameters, and identify common defects.
4. Familiarize with conventional and advanced metal forming techniques and their industrial applications.
5. Enhance the ability to select suitable metal forming processes for engineering applications.

**Course outcomes:** After completion of the course student will be able to

**CO1:** Explain the fundamentals of plastic deformation and the principles of various metal forming processes.

**CO2:** Analyze sheet metal forming operations and evaluate process parameters for different forming applications.

**CO3:** Apply theoretical concepts to analyze forging, rolling, extrusion, and drawing processes.

**CO4:** Evaluate powder metallurgy and advanced forming processes for engineering applications.

**CO5:** Select appropriate conventional and unconventional metal forming processes based on material, product, and application requirements.

**UNIT-I**

Fundamentals of Metal Forming: Classification of metal forming processes, Mechanism of plastic deformation, Factors affecting plastic deformation, Strain hardening behavior. Recovery, Recrystallization and grain growth. Ideal & Practical stress-strain curves. Cold working, warm working and hot working. Plasticity cycle. Yield criteria.

**UNIT-II**

Sheet Metal Working: Formability tests for sheet metals. Erichsen and Fukui tests. F.L.D. and Shape analysis concepts. Sheet metal dies, Process parameters and estimation of loads in shearing, bending, deep drawing and spinning operations. Superplastic forming, Stretch forming. Fine blanking, Incremental forming.

**UNIT-III**

Analysis of plastic deformation: Forging, Rolling, Extrusion, rod/wire drawing and tube drawing – Effect of friction – calculation of forces, work done – Process parameters, equipment

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used – Defects – applications – Recent advances in Forging, Rolling, Extrusion and Drawing processes – Design consideration in forming. Hydrostatic Extrusion. Metal working lubricants.

**UNIT-IV**

Powder Metallurgy Technique: Advantages – applications – Powder preform forging –powder rolling – Tooling, process parameters and applications. Orbital forging –Isothermal forging – Hot and cold isostatic pressing – High speed extrusion.

**UNIT-V**

Unconventional Forming: High energy rate forming. Merits and limitations of HERF Processes. Principle, merits, limitations and applications of Explosive forming, electromagnetic forming, electro -hydraulic forming and water hammer forming. Forming with rubber pads.

**Suggested Reading:**

1. Geoffrey W. Rowe, "An introduction to the Principles of Metal Working", First Edition, St Martin's Press, London, 1965.

2. Serope Kalpak Jain, "Mechanical Processing of Materials", D.Van Nostr and Company, Inc., First Edition, Princeton, New Jerseey, 1955.

3. Surender Kumar, "Principles of Metal Working", Second Edition, Oxford & IBH Publishing Co. Pvt. Ltd., 1985.

4. P.C. Sharma, "A Text Book of Production Engineering", Eleventh Edition, S.Chand & Co. Ltd. New Delhi, 2013.

5. G.E. Dieter, "Mechanical Metallurgy", Third Edition, McGraw - Hill Publications, 1988.

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# ADDITIVE MANUFACTURING TECHNOLOGIES AND APPLICATIONS

**Code: PHD6004ME**

***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours***

***SEE: 100 marks*** | ***Credits: 3***

Course Objectives

1. Understand the fundamentals, principles, and process chain of Additive Manufacturing (AM).
2. Develop knowledge of various additive manufacturing technologies, materials, and rapid tooling methods.
3. Learn the concepts of AM data formats, reverse engineering, topology optimization, and AM software.
4. Familiarize with the applications of additive manufacturing in engineering, medical, aerospace, and other industrial sectors.
5. Enhance the ability to select appropriate AM processes for product development and innovative manufacturing applications.

**Course outcomes:** After completion of the course student will be able to:

**CO1** Interpret the features of Additive Manufacturing and compare it with conventional CNC Technology

**CO2** Illustrate the working principle, advantages, limitations and applications of various Additive Manufacturing Technologies and Rapid Tooling systems

**CO3** Interpret various types data formats and STL file errors used in AM and identify the role of Topology optimization in AM

**CO4** Analyse the features of different types of software's used in 3D Printing

**CO5** Apply the knowledge of various AM technologies for developing new and innovative applications

## UNIT – I

Introduction: Prototyping fundamentals: Need for time compression in product development, Need for Additive Manufacturing, Historical development, Fundamentals of Additive Manufacturing, AM Process Chain, Advantages and Limitations of AM, Commonly used Terms, Classification of AM process, Fundamental Automated Processes: Distinction between AM and CNC, other related technologies. Role of AM in Industry 4.0.

## UNIT – II

Working principle, Specifications, Materials used, Process, Applications, Advantages and Disadvantages, Case studies of the following AM Technologies Vat Photo polymerization AM Systems: Photopolymers, photo polymerization Stereo lithography Apparatus (SLA), Direct Light Processing (DLP) and Continuous Direct Light Processing (CDLP). Material Jetting AM Systems: Material Jetting, Nano particle jetting and Drop-On-Demand (DOD) material jetting

Binder Jetting AM Systems: Three-dimensional Printing (3DP). Material Extrusion AM Systems: Fused Deposition Modelling (FDM)

**UNIT – III**

Working principle, Specifications, Materials used, Process, Applications, Advantages and Disadvantages, Case studies of the following AM Technologies Powder Bed Fusion AM Systems: Selective laser sintering (SLS), Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM). Direct Energy Deposition (DED) AM Systems: Laser Engineered Net Shaping (LENS) and Electron Beam Additive Manufacturing (EBAM). Sheet Lamination AM Systems: Laminated Object Manufacturing (LOM) and Ultrasonic Additive Manufacturing (UAM). Rapid Tooling: Introduction to Rapid Tooling (RT), Conventional Tooling Vs RT, Need for RT, Classification of Rapid Tooling, Direct and Indirect Tooling Methods, Soft and Hard Tooling methods.

**UNIT – IV**

Reengineering in AM: Reengineering Engineering (RE) Methodologies and Techniques, Selection of RE systems, RE software, RE hardware, RE in product development AM Data Formats: STL Format, STL File Problems, Consequence of Building Valid and Invalid Tessellated Models, STL file Repairs: Generic Solution, Slicing Algorithms: Rock Algorithm, Crawford's algorithm, Other Translators, Newly Proposed Formats. Mesh Refining by Sub division Techniques, Topology optimization and Additive Manufacturing. AM Software's: Need for AM software, Features of various AM software's like Magics, Mimics, Solid View, View Expert, 3 D View, Velocity 2, Rhino, STL View 3 Data Expert and 3 D doctor, SurgiGuide, 3-matic, Simplant, MeshLab.

**UNIT –V**

AM Applications: Application – Material Relationship, Application in Design, Engineering Analysis and Planning, Aerospace, Automotive, Jewellery, Coin, GIS, Arts, Architecture. Medical and Bioengineering Applications, Forensic Science and Anthropology, Visualization of Biomolecules. Cost Estimation in AM: Cost Model, Build Time Model, Laser Scanning Vat Photopolymerization Example, Life-Cycle Costing.

**Suggested Readings:**

1. Ian Gibson, David W Rosen, Brent Stucker, "Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", Second Edition, Springer, 2010.

2. Chee Kai Chua and Kah Fai Leong, "3D Printing and Additive Manufacturing Principles and Applications" Fifth Edition, World scientific, 2017.

3. Frank W.Liou "Rapid Prototyping & Engineering Applications", Second Edition, CRC Press, Taylor &Francis Group, 2019.

4. Rafiq Noorani, "Rapid Prototyping: Principles and Applications in Manufacturing", First Edition, John Wiley & Sons, 2006.

5. NPTEL Course on Rapid Manufacturing.

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# EXPERIMENTAL TECHNIQUES AND DATA ANALYSIS

**Code: PHD6005ME**

***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours***

***SEE: 100 marks*** | ***Credits: 3***

**Course Objectives**

1. Understand the principles and applications of experimental techniques and measurement systems used in Mechanical Engineering.
2. Develop the ability to select appropriate instruments and characterization techniques for engineering experiments.
3. Learn methods of experimental design, data collection, statistical analysis, and optimization.
4. Gain knowledge of data interpretation using statistical tools, regression analysis, ANOVA, and response surface methodology.
5. Familiarize with Taguchi methods and modern experimental techniques for improving engineering processes and product quality.

**Course Outcomes:**

After completion of the course student will be able to:

CO1 Estimate cutting force using strain gauges, transducers and strain by photo elasticity, holography, interferometer, Strain gauges.

CO2 Estimate temperature by thermistors, electrical resistance, pyrometers, thermo couples, bimetallic etc and flow measurement by laser Doppler, hot wire anemometer, ultrasonic, shadow graphs.

CO3 Examine the microstructure of a given material under different working condition and Measurement of surface finish and surface roughness.

CO4 Propose an appropriate statistical model for a given experimental data and estimate the contribution of each parameter by ANOVA

CO5 Apply orthogonal array, optimize the response function and estimate loss function for experimental design

**UNIT – I**

Measurement of Cutting Forces: Strain gauge and piezoelectric transducers and their characteristics. Dynamometer construction, Bridge circuits. Instrumentation and calibration. Displacement and strain measurements by photo-elasticity. Holography, interferometer, Moiré techniques, strain gauge rosettes.

**UNIT –II**

Temperature Measurement: Circuits and instrumentation for different transducers viz, bimetallic, expanding fluid, electrical resistance, thermistor, thermocouples, pyrometers. Flow Measurement: Transducers for flow measurements of Non-compressible and compressible fluids. Obstruction and drag methods. Vortex shredding flow meters. Ultrasonic, Laser Doppler

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and Hotwire anemometer. Flow visualization techniques, Shadow graphs, Schlieren photography. Interferometer.

**UNIT – III**

Metallurgical Studies: Optical microscopy, Scanning Electron Microscopy and Transmission Electron Microscopy, X-Ray diffraction, Bragg's Law and its application for studying crystal structure and residual stresses. Electron spectroscopy, Surface Measurements: Micro hardness, roughness, accuracy of dimensions and forms. 3 -D co-ordinate measuring machines.

**UNIT - IV**

Experiment design & data analysis: Statistical methods, Randomized block design, Latin and orthogonal squares, factorial design, Replication and randomization, response surface methodology. Data Analysis: Deterministic and random data, uncertainty analysis, tests for significance: Chi -square, student's t-test. Regression modelling, direct and interaction effects. ANOVA, F-test. Time Series analysis, Autocorrelation and autoregressive modelling.

**UNIT – V**

Taguchi Methods: Experiment design and planning with orthogonal arrays and linear graphs. Additive cause effect model. Optimization of response level. Identification of Design and noise factors. Performance evaluation and Optimization by signal to noise ratios. Concept of loss function and its application.

**Suggested Reading:**

1. Holman, J.P.: Experimental Methods for Engineers, 8th Edition, McGraw Hill Int., New York, 2012.

2. Venkatesh, V.C., and Chandrasekharan, Experimental Methods in Metal Cutting, 1st Edition, Prentice Hall of India, Delhi, 1982.

3. Raymond H. Mayers, Douglas C. Montgomery, Christine M. Anderson-Cook, Response Surface Methodology: Process and Product Optimization using Designed Experiment, 3rdedition, John Wiley & Sons, New York, 2001

4. D.C. Montgomery, Design and Analysis of Experiments, 5th edition, John Wiley & Sons, New York, 2001

5. A.M. Dean, and D. T.Voss, Design and Analysis of Experiments (Springer text in Statistics), 1st Edition, Springer, 1999.

6. Tapan P. Bagchi, Taguchi Methods Explained, 1st Edition, Prentice Hall of India, Delhi, 1993.

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# MATERIAL SCIENCE AND TECHNOLOGY

**Code: PHD6006ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the structure, properties, and behavior of engineering materials and their relationship with processing and performance.
2. Develop knowledge of metallic, non-metallic, and advanced materials used in Mechanical Engineering applications.
3. Learn the principles of deformation, strengthening mechanisms, fracture, fatigue, creep, and material failure.
4. Gain knowledge of phase transformations and heat treatment processes for tailoring material properties.
5. Familiarize with advanced materials, characterization techniques, and their applications in modern engineering.

**Course Outcomes:** At the end of the course, the scholar will be able to:

CO1. Explain crystal structures, defects, and strengthening mechanisms in materials.

CO2. Analyze mechanical behaviour including fracture, fatigue, and creep of engineering materials.

CO3. Classify and compare ferrous, non-ferrous, and advanced metallic alloys including nickel-based superalloys.

CO4. Evaluate the properties and applications of non-metallic materials such as ceramics, polymers, and composites.

CO5. Apply principles of heat treatment to control properties of ferrous and non-ferrous materials.

**UNIT – I**

Crystal structures: BCC, FCC, HCP structures., Atomic packing factor, coordination number and crystallographic directions and planes.

Crystal imperfections: Point defects, line defects, surface defects and volume defects. Plastic deformation of metals: Slip and twinning, strain hardening, plasticity range., Recovery, recrystallization and grain growth.

Strengthening mechanisms in metals: Grain boundary strengthening (Hall–Petch, relationship),Solid solution strengthening, Precipitation hardening, Work hardening

Effect of grain size on mechanical properties.

**UNIT – II**

Stress–strain behaviour of metals., True stress and true strain., Mechanical properties: Elasticity, plasticity, ductility, toughness and resilience.

Mechanical testing methods: Tensile testing, hardness testing (Brinell, Rockwell, Vickers), impact testing.

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Failure of materials: Ductile fracture, Brittle fracture, Fatigue, Creep mechanisms and testing., Fracture mechanics concepts: Stress intensity factor and fracture toughness.
Failure analysis and fractography.

**UNIT – III**

Classification of metallic materials., Ferrous alloys, Plain carbon steels, alloy steels, cast irons (grey iron, ductile iron, malleable iron). Non-ferrous alloys: Aluminium alloys, copper alloys magnesium alloys, titanium alloys. Nickel-based alloys and superalloys, Structure, properties and applications in aerospace and high-temperature environments. Corrosion resistance and high temperature behaviour of metallic alloys. Applications of advanced metallic materials in engineering.

**UNIT – IV**

Classification of non-metallic materials. Ceramics-Structure, properties and engineering applications. Thermoplastics and thermosetting plastics. Polymer structure and mechanical behaviour. Types of composites: particulate, fibre reinforced and laminated composites.
Properties and applications in aerospace, automotive and structural engineering. Nanomaterials, smart materials and biomaterials.

**UNIT – V**

Phase rule and equilibrium phase diagrams. Iron–Iron carbide equilibrium diagram.
Effect of alloying elements on phase diagrams. Isothermal transformation (TTT) diagrams and continuous cooling transformation (CCT) diagrams.
Microstructural transformations in steels.
Heat treatment processes: Annealing, Normalizing, Hardening, Tempering, Hardenability of steels.
Surface hardening and case hardening processes: carburizing, nitriding and induction hardening.

**Suggested Readings:**

1. W. D. Callister Jr., *Materials Science and Engineering: An Introduction*, 10th ed. Hoboken, NJ, USA: Wiley, 2018.
2. V. Raghavan, *Materials Science and Engineering: A First Course*. New Delhi, India: PHI Learning, 2015.
3. S. H. Avner, *Introduction to Physical Metallurgy*, 2nd ed. New York, NY, USA: McGraw-Hill, 1964.
4. G. Krauss, *Steels: Processing, Structure, and Performance*. Materials Park, OH, USA: ASM International, 2005.
5. W. E. Bryson, *Heat Treatment, Selection and Application of Tool Steels*. Munich, Germany: Hanser Publishers, 2005.

# TOOL ENGINEERING

**Code: PHD6007ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the principles of cutting tool design and manufacturing for various machining operations.
2. Develop knowledge of the design and application of press tools, jigs, fixtures, and gauges.
3. Learn the design principles of forging dies and tooling for manufacturing processes.
4. Gain the ability to select suitable tooling based on machining requirements, accuracy, and productivity.
5. Familiarize with modern tooling practices and economic aspects of tool design and manufacturing.

**Course Outcomes:** After completion of the course student will be able to
CO1 Acquire knowledge in single point cutting tools, form tools.
CO2 Interpret the design and manufacturing of multi point cutting tool to machine a required job.
CO3 Design a die and punch for blanking, piercing, drawing and bending operations. CO4 Design a location and clamping system for a given component.
CO5 Design of gauge to measure a given component and acquire knowledge in forging die design and economics of tooling

**UNIT-I**

Design of single-point cutting tools: Tool strength and rigidity calculation, selection of tool angles, chip breakers, carbide, tipped tools. Manufacturing of single point cutting tool. Form Tools: Types of form tools, method of determining the profile of circular and flat form of tool, analytical and graphical method. Cutting principle by form generation gear shapers & hobs.

**UNIT-II**

Design of Multi Point Cutting tools: Geometry, types and design of Twist drills, Reamers, Milling cutters, broaches. Manufacturing of Multi Point Cutting Tools: Manufacturing of Twist drills, Reamers, Milling cutters, broaches.

**UNIT-III**

Design of Press Tools: blanking, piercing, bending and drawing operations, center of pressure clearances, strip layout, punch force, blank size, number of draws, single, compound and progressive press tools. Drawing dies,Deep Drawing of Cups, Blank diameter, Drawing force Design of bending die.

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Design of Jigs and Fixtures: Principles of location and clamping, locating and clamping elements and their standardization, Diamond pin, Redundant location, fool proofing, classification of Drill Jigs, Drill bushings and liners. Quick clamping devices. Designing jig and fixture. Design principles of Drilling Jigs, Milling fixtures, welding fixtures, fixturing of NC machines.

**UNIT-V**

Forging Die Design: Allowances, Forging process, Forging die design, Drop forging Dies and auxiliary tools, Upset forging. Gauge design: Gauge principles, types, gauge allowances and tolerance, materials for gauges. Economics of Tooling: Economics if small tool selection, Breakeven point analysis, Economic lot size, Tooling for Automats: Cam design for automats

**Suggested Reading:**


1. Society of Manufacturing Engineers, *Fundamentals of Tool Design*. Dearborn, MI, USA: SME.
2. P. C. Sharma, *A Textbook of Production Engineering*, 8th ed. New Delhi, India: S. Chand, 1999.
3. G. R. Nagpal, *Tool Engineering and Design*, 1st ed. New Delhi, India: Khanna Publications, 2000.
4. P. H. Joshi, *Press Tools: Design and Construction*, 1st ed. New Delhi, India: S. Chand, 2017.
5. J. G. Nee, *Fundamentals of Tool Design*, 6th ed. Dearborn, MI, USA: Society of Manufacturing Engineers, 2010.
6. P. H. Joshi, *Jigs and Fixtures*, 3rd ed. New Delhi, India: Tata McGraw-Hill Education, 2017.
7. K. Venkataraman, *Design of Jigs, Fixtures and Press Tools*. Chichester, U.K.: John Wiley & Sons Ltd., Athena Academic, 2015.


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# ADVANCED ENERGY SYSTEMS

**Code: PHD6008ME**

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| ***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours*** |
| ***SEE: 100 marks*** | ***Credits: 3*** |

**Course Objectives**

1. Understand the principles and applications of renewable and advanced energy systems.
2. Develop knowledge of solar, wind, biomass, waste heat recovery, and fuel cell technologies.
3. Learn the design, performance analysis, and operation of sustainable energy systems.
4. Evaluate the efficiency and feasibility of advanced energy technologies for power generation and energy management.
5. Familiarize with emerging energy technologies and their role in sustainable development and clean energy production.

**Course Outcomes:** On completion of this course, the student will be able to do:

CO-1 Identify the need and promise of simultaneously alternative and "clean" energy technologies such as renewable energy systems

CO-2 Expose to the diversity of beneficial applications currently utilizing renewable energy

CO-3 Introduce societal catalysts and challenges regarding renewable energy Implementation

CO-4 Evaluate the performance of thermal systems using of energy management principles

CO-5 Explore the utilization of renewable energy within developing or developed regions

**Unit-I**

Solar Energy: Solar radiation–measurement, collection and storage, Solar Thermal Systems, Design of flat plate and parabolic concentrating collectors, Solar power plants. Photo voltaic power systems. Application of SPV.

**Unit–II**

Wind Energy: Estimation of wind energy potential. Horizontal and Vertical axis wind turbine rotors. Aerodynamic design considerations for wind rotor blades. Wind electric generators-operation and control. Aero generators for battery charging.

**Unit–III**

Biomass Energy: Sources of biomass. Biomass for Energy production. Methane production. Biomass energy conversion technologies. Use of Biomass gasifier, Types of gasifiers. Biomass Power generation using agricultural residues. Introduction of Hybrid energy systems.

**Unit-IV**

Waste Heat Recovery: Principles and Devices - Regenerators and Recuperators. Analysis of heat recovery systems. Design of waste heat recovery boilers. Combined cycle power plants based on waste heat recovery.

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**Unit-V**

Fuel Cell Technology: Introduction, Classification of fuel cells, Operating principles, Thermodynamic Aspects of Electrochemical Energy Conversion, Electrochemical kinetics, Performance of fuel cells, fuel cell components - Alkaline Fuel Cells, (AFC), Solid Oxide Fuel Cells (SOFC), Proton Exchange Membrane Fuel Cells (PEMFC), Characteristics of fuel cells. Case studies

**Suggested Readings:**


1. J. A. Duffie and W. A. Beckman, *Solar Engineering of Thermal Processes*, 3rd ed. New York, NY, USA: John Wiley & Sons, 2006.
2. P. Gipe, *Wind Energy Comes of Age*. New York, NY, USA: John Wiley & Sons, 1995.
3. N. H. Ravindranath and D. O. Hall, *Biomass, Energy and Environment: A Developing Country Perspective*. Oxford, U.K.: Oxford University Press, 1995.
4. R. Goldstick, *Principles of Waste Heat Recovery*. Lilburn, GA, USA: Fairmont Press, 1984.
5. J. Larminie and A. Dicks, *Fuel Cell Systems Explained*, 2nd ed. Chichester, U.K.: John Wiley & Sons, 2003.


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# POWER PLANT STEAM GENERATORS

**Code: PHD6009ME**

| | |
|---|---|
| ***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours*** |
| ***SEE: 100 marks*** | ***Credits: 3*** |

**Course Objectives**

1. Understand the principles of steam generation and the operation of modern power plant boilers.
2. Develop knowledge of different types of steam generators, combustion systems, and fuel handling methods.
3. Learn the design principles of furnaces, burners, and steam generation equipment.
4. Evaluate the performance, efficiency, and environmental aspects of power plant steam generators.
5. Familiarize with boiler maintenance, safety practices, and recent advancements in steam generation technologies.

**Course Outcomes:** On completion of this course, the student will be able to:

CO-1 Understand the various sources of energy.

CO-2 Identify Equipment, Plant layout, principle of working of various plants.

CO-3 Understand the various combustion systems.

CO-4 Understand the working principles of various boilers

CO-5 Design furnaces and burners

**Unit– I**

Introduction-steam generation, Nucleate & Film Boiling, circulation ratio, Natural, Assisted and Forced Circulation Boilers. Super Critical Boilers.

**Unit– II**

Requirements in modern boilers, Types of steam generators and their construction and application, Fuels and Fuel Handling systems, for steam generators.

**Unit– III**

Air-handling systems, Combustion in combustion systems with different types of fuels, combustion calculations, Once-thro" boilers, Fluidised bed combustion boilers, Cyclone furnace boilers.

**Unit– IV**

Furnace sizing, Burner selection and design combined cycle power plant steam generators, Emissions from steam generators and its control.

**Unit– V**

Boiler maintenance, safety regulation and inspection, Ash handling Case study of typical modern boiler systems.

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**Suggested Readings:**


1. W. J. Kearton, *Steam Turbine Theory and Practice*. New Delhi, India: CBS Publishers, 2004.
2. I. G. C. Dryden, *The Efficient Use of Energy*, 2nd rev. ed. Oxford, U.K.: Butterworth-Heinemann, 1982.
3. J. A. Fay and D. Golomb, *Energy and the Environment: Scientific and Technological Principles*, 2nd ed. New York, NY, USA: Oxford University Press, 2011.
4. A. B. Gill, *Power Plant Performance*. Oxford, U.K.: Butterworth-Heinemann, 1996.
5. R. K. Hegde, *Power Plant Engineering*. Noida, India: Pearson Education, 2015.


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# ENERGY SYSTEMS AND MANAGEMENT

**Code: PHD6010ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the principles of energy systems, energy storage, and energy management.
2. Develop knowledge of energy conservation, energy efficiency, and waste heat recovery techniques.
3. Learn methods for evaluating and improving the performance of thermal and industrial energy systems.
4. Gain the ability to plan, manage, and assess energy utilization through energy auditing and economic analysis.
5. Familiarize with modern energy management practices and sustainable energy technologies.

**Course Outcomes:** On completion of this course, the student will be able to:

CO-1 Understand the fundamentals of energy management

CO-2 Apply the principles of thermal engineering and energy management to improve the performance of thermal systems.

CO-3 Analyze the methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems.

CO-4 Design viable energy projects.

CO-5 Gain knowledge in carrying out energy auditing

**Unit– I**

Introduction: Review of the concepts of Thermodynamics, Fluid Mechanics and Heat Transfer, Need for energy storage, Grid balancing: Supply and demand concept for energy management. Heat transfer equipment- Heat exchangers, Steam plant Energy storage Methods and systems: Thermal, Electrical and Mechanical energy storage methods in thermal power plants.

**Unit– II**

Direct Energy Conversion methods: Magneto-hydrodynamic (MHO) power generation, Thermionic power generation, Thermoelectric power generation, Fuel cells, Hydrogen energy system Heat recovery systems: Incinerators, regenerators and boilers

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**Unit– III**

Energy Conservation: Methods of energy conservation and energy efficiency for buildings, air conditioning, heat recovery and thermal energy storage systems

**Unit– IV**

Energy Management: Principles of Energy Management, Energy demand estimation, Organising and Managing Energy Management Programs, Energy pricing

**Unit– V**

Energy Audit: Purpose, Methodology with respect to process Industries, Characteristic method employed in Certain Energy Intensive Industries, Economic Analysis: Scope, Characterization of an Investment Project .

**Suggested Readings:**


1. B. K. De, Energy Management, Audit and Conservation, 2nd ed. New Delhi, India: Vrinda Publications, 2010.
2. S. Doty and W. C. Turner, Energy Management Handbook, 7th ed. Lilburn, GA, USA: Fairmont Press, 2009.
3. A. Thumann and W. J. Younger, Handbook of Energy Audits, 9th ed. Lilburn, GA, USA: Fairmont Press, 2012.
4. W. R. Murphy and G. McKay, Energy Management. Oxford, U.K.: Butterworth-Heinemann, 2009.
5. D. Yogi Goswami and F. Kreith, Energy Management and Conservation Handbook, Boca Raton, FL, USA: CRC Press, 2007.


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# HEAT TRANSFER AND HEAT EXCHANGERS IN POWER PLANTS

**Code: PHD6011ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the fundamental principles of heat transfer and their application in power plant systems.
2. Develop knowledge of conduction, convection, radiation, boiling, and condensation heat transfer mechanisms.
3. Learn the analysis and design of heat exchangers used in thermal power plants.
4. Evaluate the performance of heat transfer equipment and power plant heat exchangers under different operating conditions.
5. Familiarize with advanced heat transfer analysis and thermal system design for efficient power plant operation.

**Course Outcomes:** On completion of this course, the student twill be able to:

CO-1 Formulate 2D heat conduction problems in rectangular, cylindrical and spherical coordinate system by transforming the physical system into a mathematical model.

CO-2 Compute boundary layer for laminar and turbulent flows and convective heat transfer coefficients

CO-3 Solve problem in radiation heat transfer and numerical methods.

CO-4 Analyse the mechanism which is involved in boiling and condensation

CO-5 Compute different types of heat exchangers used in an Industries and that leads to design heat exchanges

**Unit-I**

Conduction: Two-dimensional steady state problems – Cartesian and cylindrical geometries. General unsteady state heat conduction equation in cylindrical and spherical co-ordinates. Periodic and non-periodic temperature variations within a semi-infinite solid within infinite wall. Extended Surfaces (Fins): Heat transfer from a straight fin (Plate) of a uniform cross section, Error in measurement of temperature in a thermometer well, Fin efficiency, Applications.

**Unit-II**

Convection: Approximate integral boundary layer analysis. Heat transfer in the laminar flow inside smooth tubes. Analogy between momentum and heat transfer in turbulent flow over a

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plane surface and turbulent flow in a tube. Empirical correlations – free convection (vertical and horizontal plates).

**Unit-III**

Radiation: Enclosures with black surfaces, Enclosures with gray surfaces. Numerical Methods–finite difference techniques, Gas radiation.

**Unit-IV**

Boiling and condensation: Boiling: Boiling phenomenon, Boiling curve, Mechanism of nucleate boiling, Stable film boiling, Forced convection boiling.

Condensation: Condensation phenomenon, Film Condensation on a vertical surface, Condensation outside a horizontal tube or a tube bank, Condensation inside a horizontal tube. Drop wise Condensation. Introduction to two-phase flow: Simple momentum and energy equations.

**Unit-V**

Heat Exchangers: Parallel flow, counter flow and cross flow heat exchangers, multi-pass shell and tube heat exchangers and design. Plate type of heat exchangers, and Compact Heat Exchangers.

Power plant heat exchangers: Condensers, Feed Water Heaters, Evaporators, Dearators, Economizer, Air Preheaters, and their design considerations. Principles of simultaneous heat and mass transfer. Analysis of cooling towers.

**Suggested Readings:**


1. F. Kreith and M. S. Bohn, *Principles of Heat Transfer*. New York, NY, USA: Harper & Row Publishers, 1986.

2. G. E. Myers, *Analytical Methods in Conduction Heat Transfer*. New York, NY, USA: McGraw-Hill, 1971.

3. W. M. Kays and M. E. Crawford, *Convective Heat and Mass Transfer*. New Delhi, India: Tata McGraw-Hill Publishing Co. Ltd., 1993.

4. J. P. Holman, *Heat Transfer*. New York, NY, USA: McGraw-Hill Book Company, 2010.

5. B. K. Dutta, *Heat Transfer*. New Delhi, India: Prentice Hall of India, 2001.

6. F. P. Incropera, D. P. DeWitt, T. L. Bergman, and A. S. Lavine, *Fundamentals of Heat and Mass Transfer*, 8th ed. Hoboken, NJ, USA: John Wiley & Sons, 2017.


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# VIBRATION ANALYSIS AND CONDITION MONITORING

**Code: PHD6012ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the fundamentals of mechanical vibrations and their significance in machine design and operation.
2. Develop knowledge of vibration analysis for single, two, and multi-degree-of-freedom systems.
3. Learn the principles and techniques of condition monitoring and fault diagnosis in mechanical systems.
4. Gain the ability to analyze vibration signals using modern measurement and diagnostic techniques.
5. Familiarize with advanced condition monitoring methods for improving the reliability and maintenance of engineering systems.

**Course Outcomes**: On completion of this course, the student will be able to:

**CO-1** Fully understand importance of vibrations in mechanical design of machine parts that operate under vibratory conditions.

**CO-2** Write differential equation of motion of vibratory system and understand free and forced modes of vibration

**CO-3** Obtain linear vibratory models of dynamic systems of varying complexity (DOF, MDOF)

**CO-4** Apply various condition monitoring techniques available in the literature.

**CO-5** Classify and use various devices available to record interpret and understand the vibration data.

**Unit– I**

Causes and effects of vibration. Vibrations of Single Degree of freedom systems. Free, Damped and Forced vibrations.

**Unit– II**

Two Degree of freedom systems. Bending vibrations of two degree of freedom systems, Steady state and transient characteristics of vibration, vibration absorber and vibration isolation.

**Unit– III**

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Multi degree of freedom systems: Dunkerley method, Rayleigh method, stodola method and holzers method. Modal analysis.

**Unit– IV**

Introduction to Condition Monitoring, Failure types, investigation and occurrences. Causes of failure, Vibration measuring instruments, vibration transducers, signal conditioning elements. Display and recording elements. Vibration meters and analyzers. Condition Monitoring through vibration analysis. Frequency analysis, Filters, Vibration signature of active systems, vibration limits and standards.

**Unit– V**

Contaminant analysis, SOAP and other contaminant monitoring techniques. Special vibration measuring techniques - Change in sound method, Ultrasonic measurement method, Shock pulse measurement, Kurtosis, Acoustic emission monitoring, Cepstrum analysis, Modal analysis, critical speed analysis, Shaft –orbit & position analysis. Application of Vibration analysis & Condition Monitoring in the design and development of turbomachines. Case studies

**Suggested Readings:**


1. S. S. Rao, *Mechanical Vibrations*, 6th ed. Hoboken, NJ, USA: Pearson, **2017**.
2. V. P. Singh, *Mechanical Vibrations*. New Delhi, India: Dhanpat Rai Publications, **2015**.
3. R. A. Collacott, *Mechanical Fault Diagnosis and Condition Monitoring*. London, U.K.: Chapman & Hall, **1977**.
4. J. S. Mitchell, *Introduction to Machinery Analysis and Monitoring*. Tulsa, OK, USA: PennWell Publishing Company, **1981**.
5. J. S. Rao, *Vibration Condition Monitoring of Machines*. Boca Raton, FL, USA: CRC Press, **2000**.
6. B. C. Nakra, G. S. Yadava, and L. Thuested, *Vibration Measurement and Analysis*. New Delhi, India: National Productivity Council, **1979**.


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# ALTERNATE FUELS AND EMISSIONS

**Code: PHD6013ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the need, properties, and production of alternate fuels for internal combustion engines.
2. Develop knowledge of the performance and emission characteristics of engines operating on alternate fuels.
3. Learn the production, storage, and utilization of gaseous, liquid, and bio-based alternative fuels.
4. Gain knowledge of engine emission formation, measurement techniques, and emission control methods.
5. Familiarize with current emission standards and sustainable fuel technologies for reducing environmental impact.

**Course Outcomes:** On completion of this course, the student will be able to:

CO-1 Understand the need of alternate fuels

CO-2 Evaluate the performance of the engine with alternate fuels and blends with petroleum derived fuels.

CO-3 Examine the viable production and storage methods of alternate fuels.

CO-4 Measure the pollutant emissions as per standards and describe emission control methods.

CO-5 Evaluate the production methods in other countries and estimating time in growth

**Unit– I**

Introduction: Present energy scenario (worldwide and India)- Statistics of petroleum fuels- of liquid and gaseous fuels in Automobiles-Problems with highly exploited petroleum derived fuels- Desirable properties of a good alternate fuel – Availability and properties of alternate fuels, ASTM standards.

Alcohols: General Use of Alcohols – Thermo-combustion properties as Engine fuel – Gasoline and alcohol blends – Production methods of widely used alcohols-Performance in SI and CI Engines – Methanol and ethanol and Gasoline/diesel blends – Combustion Characteristics in engine – emission characteristics-Modification required to operate with alcohols and its blends with petrol and diesel-brief details of flexi fuel engines(FFE)-use of higher alcohols.

**Unit– II**

Natural Gas, LPG, CNG: Use of natural gas as CNG and LNG-Availability of CNG and LNG properties, modification required to use in engines – performance and emission characteristics of CNG using LPG in SI & CI engines. -Production and storage of CNG/LNG.

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Biogas: Production methods of biogas, properties of biogas as a fuel, performance and emission characteristics of engine with biogas and its blends with petrol/diesel-brief information on compressed Biogas and its storage.

**Unit– III**

Vegetable oils: Characteristics of vegetable oils as alternate fuel- edible and non-edible vegetable oils-conversion of vegetable oils into diesel like fuel(biodiesel) -esterification, blending and micro- emulsions-Performance and emission characteristics of engines with biodiesel and blends-B20.

Hydrogen: Suitable characteristics of hydrogen fuel- hydrogen production methods- storage of hydrogen-use of hydrogen as fuel in engines -Hydrogen in fuel cells.

**Unit– IV**

Engine Emissions: Harmful effects of engine-out emissions-Mechanism of formation of pollutant emissions such as carbon monoxide, unburned hydrocarbons, oxides of hydrogen and aldehydes.

**Unit– V**

Emission measurement and control methods: Measurement of pollutants using flame ionisation detection, NDIR, chemiluminescent analyser and particulate matter(soot/smoke)-Emission norms- EURO and Bharat stage Engine emission control methods-in cylinder and after treatment methods.

**Suggested Readings**:


1. M. K. Gajendra Babu and K. A. Subramanian, *Alternative Transportation Fuels: Utilisation in Combustion Engines*. Boca Raton, FL, USA: CRC Press, 2013.
2. A. P. Singh and Y. C. Sharma, *Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines*. Singapore: Springer, 2020.
3. B. P. Pundir, *Engine Emissions: Pollutant Formation and Advances in Control Technology*. New Delhi, India: Narosa Publishing House, 2013.
4. A. S. Ramadhas, *Alternative Fuels for Transportation*. Boca Raton, FL, USA: CRC Press, 2012.
5. J. B. Heywood, *Internal Combustion Engine Fundamentals*, 2nd ed. New York, NY, USA: McGraw-Hill Education, 2018.


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# EXPERIMENTAL TECHNIQUES IN TURBOMACHINES

**Code: PHD6014ME**

***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours***

***SEE: 100 marks*** | ***Credits: 3***

**Course Objectives**

1. Understand the principles of experimental methods and measurement techniques used in turbomachinery.
2. Develop knowledge of instrumentation, calibration, and data acquisition systems for turbomachinery experiments.
3. Learn flow measurement and flow visualization techniques for analyzing turbomachinery performance.
4. Gain the ability to design, conduct, and analyze experiments using appropriate experimental methods.
5. Familiarize with modern diagnostic techniques, data processing, and uncertainty analysis for turbomachinery research.

**Course Outcomes:** On completion of this course, the student will be able to:

**CO-1** Familiarize to experimental design protocols and plan for design

**CO-2** Understand the calibration methods and also data acquisition systems and usage.

**CO-3** Demonstrate flow visualization techniques and flow measurement devices

**CO-4** Design and conduct experiments, as well as to organize, analyze and interpret data to produce meaningful conclusions and recommendations

**CO-5** Identify, formulate and solve complex turbomachinery problems

**Unit– I**

Experiment planning, experiment design factors. Classification of measurement techniques. Conventional techniques for measurement of Flow, Pressure, Temperature and Velocity in turbomachinery passages.

**Unit– II**

Temperature measuring devices – Thermo-electric thermometry and pyrometry. Instantaneous pressure measurement using pressure transducers, Pitot tube, probes. Boundary layer measurement, Calibration of probes.

**Unit– III**

Wind tunnels: Schematic layout of wind tunnel with test section, subsonic, transonic and supersonic wind tunnels. Measurement of turbulence using a Hot wire anemometer and Laser Doppler anemometer.

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**Unit– IV**

Calibration methods and signal processing techniques. General data acquisition system Data transmission, A/D and D/A conversion, Recorders with digital display. Data collection and storage.

**Unit– V**

Flow measurement instruments, Flow Visualization techniques – conventional and optical methods. Radar Doppler and Laser Velocimeter. Brief description of error and uncertainty analysis.

**Suggested Readings:**

1. D. Japikse, *Advanced Experimental Techniques in Turbomachinery*. Oxford, U.K.: Atlantic Books, 1997.

2.J. P. Holman, *Experimental Methods for Engineers*, 8th ed. New York, NY, USA: McGraw-Hill, 2012.

3. R. Mikel, *Wind Tunnels: Models, Aerodynamics and Applications*. Newry, U.K.: Clanrye International, 2015.

4. T. G. Beckwith, R. D. Marangoni, and J. H. Lienhard V, *Mechanical Measurements*, 6th ed. Upper Saddle River, NJ, USA: Pearson Education, 2020.

5. A. K. Tayal, *Instrumentation, Mechanical Measurements and Control*, 2nd ed. New Delhi, India: Galgotia Publications Pvt. Ltd., 2008.

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# COMPUTATIONAL FLUID DYNAMICS

**Code: PHD6015ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the governing equations of fluid flow and heat transfer used in Computational Fluid Dynamics (CFD).
2. Develop knowledge of numerical methods, discretization techniques, and grid generation for CFD analysis.
3. Learn finite difference and finite volume methods for solving fluid flow and heat transfer problems.
4. Gain the ability to model and analyze engineering fluid flow problems using CFD techniques.
5. Familiarize with CFD algorithms and software for solving practical Mechanical Engineering applications.

**Course Outcomes:** On completion of this course, the student will be able to :

CO-1 Understand the governing equations of different types of fluid flow systems, averaging procedure of turbulent flow properties

CO-2 Classify second order partial differential equations, formulate finite difference equations based on accuracy, type of differencing and should be able to analyse their stability

CO-3 Discretise the problem domain

CO-4 Apply FDM and solve equations using numerical methods

CO-5 Apply Finite volume method for basic equations of heat transfer and fluid flow problems.

**Unit-I**

Review of basic equations of fluid dynamics: Continuity, Momentum and Energy equations, Navier Stokes equations, Reynolds and Favre averaged N – S equations. Differential equations for steady and unsteady state heat conduction. Differential equations for diffusion. Introduction to turbulence, Turbulence models-mixing length model, k-ε turbulence Model.

**Unit-II**

Classification of PDEs – Elliptic, parabolic and hyperbolic equations. Initial and boundary value problems. Concepts of Finite difference methods – forward, backward and central difference. Errors, Consistency, Stability analysis by von Neumann. Convergence criteria.

**Unit-III**

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Grid Generation- Types of grid O,H,C. Coordinate transformation, algebraic methods. Unstructured grid generation

**Unit-IV**

Finite difference solutions-Parabolic PDEs – Euler, Crank Nicholson, Implicit methods, Elliptic PDEs –Jacobi, Gauss Seidel, ADI, methods. FD- solution for Viscous incompressible flow using Stream function –Vorticity method & MAC method.

**Unit-V**

Introduction to Finite volume method. Finite volume formulations for diffusion equation, convection diffusion equation. Solution algorithm for pressure velocity coupling in steady flows. Use of Staggered grids SIMPLE Algorithm.

**Suggested Readings:**


1. P. Niyogi, S. K. Chakrabarty, and M. K. Laha, *Introduction to Computational Fluid Dynamics*. New Delhi, India: Pearson Education, 2005.
2. K. Muralidhar and T. Sundararajan, *Computational Fluid Flow and Heat Transfer*. New Delhi, India: Narosa Publishing House, 2003.
3. T. J. Chung, *Computational Fluid Dynamics*. Cambridge, U.K.: Cambridge University Press, 2002.
4. J. D. Anderson Jr., *Computational Fluid Dynamics: The Basics with Applications*. New York, NY, USA: McGraw-Hill, 1995.
5. S. V. Patankar, *Numerical Heat Transfer and Fluid Flow*. New York, NY, USA: Hemisphere Publishing Corporation, 1980.
6. H. K. Versteeg and W. Malalasekera, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2nd ed. New Delhi, India: Pearson Education, 2007.



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# ADVANCED CASTING & JOINING PROCESSES

**Code: PHD6016ME**

***Instruction: 3 periods per week*** ***Duration of SEE: 3 hours***

***SEE: 100 marks*** ***Credits: 3***

**Course Objectives**

1. Understand the principles of advanced casting and joining processes used in modern manufacturing.
2. Develop knowledge of casting metallurgy, solidification, gating and riser design, and casting defects.
3. Learn the fundamentals of welding metallurgy, weld design, and heat treatment for quality joining.
4. Gain knowledge of modern casting and welding technologies, automation, and computer-aided manufacturing.
5. Familiarize with the selection and application of advanced casting and joining processes for engineering applications.

**Course outcomes:** After completion of the course student will be able to

CO1 Design gating system elements for sound casting L4

CO2 Apply the knowledge of casting metallurgy to minimize casting defects L3

CO3 Identify the recent trends in casting processes and automation of foundry L2 CO4 Apply welding metallurgy concepts to design defect free welds L3

CO5 Identify the recent trends in welding processes and its automation

**UNIT - I**

Casting Metallurgy: Solidification of pure metal and alloys, grain structure of cast metals, shrinkage in cast metals, progressive and directional solidification, Degasification of the melt casting defects, refractories, metallurgical control, Inoculation, malleableizations. Castability of steel, Cast Iron- Heat treatment of cast steel, cast iron, stress relieving, solution treatment, age hardening of castings.

**UNIT - II**

Casting Design: Heat transfer between metal and mould - Design considerations in casting – Designing for directional solidification and minimum stresses- principles and design of gating and risers.

**UNIT - III**

Recent Trends in Casting and Foundry Layout: Continuous casting, Counter gravity low pressure casting, Squeeze casting and semisolid processes. Layout of mechanized foundry,

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sand reclamation, material handling in foundry, pollution control in foundry, Computer aided design of casting.

**UNIT - IV**

Welding Metallurgy and Design: Heat affected Zone and its characteristics –Carbon Equivalent of Plain and alloy steels-Schaeffler diagram, Delta Ferrite, Austenite, pearlite, Martensite. Effect of Alloying elements on microstructure- Residual stress – Distortion and its control - Weld cracks – cold and hot cracks; Liquation cracks, Hydrogen Induced cracks, Lamellar cracks. Pré and post welding heat treatments –weld joint design – welding defects – Weldability of steels, cast iron, stainless steel.

**UNIT - V**

Recent Trends In Welding: Friction welding, friction stir welding, explosive welding, diffusion bonding, high frequency induction welding, ultrasonic welding, electron beam welding, Laser beam welding, Plasma welding, Electro slag welding, narrow gap, hybrid twin wire active TIG, Tandem MIG, modern brazing and soldering techniques, induction, dip resistance, diffusion processes, Hot gas, wave and vapour phase soldering. Overview of automation of welding in aerospace, nuclear, surface transport vehicles and under water welding.

**Suggested Readings:**


1. R. S. Parmar, *Welding Engineering and Technology*, 2nd ed. New Delhi, India: Khanna Publishers, 2013.
2. N. K. Srinivasan, *Welding Technology*, 4th ed. New Delhi, India: Khanna Publishers, 2002.
3. C. R. Heine, C. R. Loper Jr., and P. C. Rosenthal, *Principles of Metal Casting*, 4th ed. New Delhi, India: Tata McGraw-Hill, 2008.
4. P. L. Jain, *Principles of Foundry Technology*, 4th ed. New Delhi, India: Tata McGraw-Hill Publishers, 2003.
5. B. H. Cary and S. C. Helzer, *Modern Welding Technology*, 6th ed. Upper Saddle River, NJ, USA: Prentice Hall, 2005.
6. J. Cornu, *Advanced Welding Systems*, Vols. I–III. Mumbai, India: Jaico Publishers, 1994.
7. J. F. Lancaster, *The Metallurgy of Welding*, 6th ed. Cambridge, U.K.: Woodhead Publishing, 1999.
8. ASM International, *ASM Handbook*, vol. 15, **Casting**. Materials Park, OH, USA: ASM International, 2004.


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# Advanced Composites

**Code: PHD6017ME**

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| ***Instruction: 3 periods per week*** | ***Duration of SEE: 3 hours*** |
| ***SEE: 100 marks*** | ***Credits: 3*** |

**Course Objectives**

1. Understand the fundamentals, classification, and mechanics of advanced composite materials.
2. Develop knowledge of polymer, metal, and ceramic matrix composites and their processing techniques.
3. Learn the design principles, manufacturing methods, and performance evaluation of composite materials.
4. Gain knowledge of advanced characterization, testing, and non-destructive evaluation techniques for composites.
5. Familiarize with the selection and application of advanced composites in aerospace, automotive, biomedical, and other engineering fields.

**Course Outcomes (COs)**

After completion of the course, the scholar will be able to:

CO1: Explain the fundamental concepts, classification, and multiscale mechanics of advanced composite materials.

CO2: Analyse the processing techniques and structural design principles of polymer matrix composites.

CO3: Evaluate the material systems, processing methods, and performance characteristics of metal matrix composites.

CO4: Understand the processing techniques, properties, and high-temperature applications of ceramic matrix composites.

CO5: Apply advanced characterization, testing, and non-destructive evaluation techniques for assessing composite material performance.

**Unit 1**

**Introduction to Composites:** Fundamentals of Composites-Evolution and need for advanced composite materials; multiscale modelling approaches including micro, meso and macro mechanics of composites. Classification of composite materials and reinforcement architectures; interface and interphase science in composites. Nano-reinforced and hybrid composite systems; fibre production technologies for glass, carbon and ceramic fibres. Structure–property–processing relationships and emerging research trends in advanced composite materials.

**Unit II**

**Polymer Matrix Composites (PMC):** Advanced polymer matrices including thermosets, thermoplastics and elastomers, and their viscoelastic behaviour. Manufacturing processes of polymer matrix composites such as hand lay-up, spray-up, resin transfer moulding (RTM/VARTM), filament winding, pultrusion, automated fibre placement (AFP), and additive manufacturing. Classical Lamination Theory (CLT) for laminate analysis; failure theories

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including Tsai–Wu and Hashin criteria; delamination and damage mechanics. Applications of polymer matrix composites in aerospace and automotive industries.

**Unit III**

**Metal Matrix Composites (MMC):** Metal Matrix Composites (MMCs): strengthening mechanisms and load transfer behaviour in metal matrix systems; selection of suitable MMC material systems and alloys. Processing techniques including powder metallurgy, advanced sintering, friction stir processing, stir casting, squeeze casting, laser cladding, and additive manufacturing. Interface characterization between reinforcement and matrix; rule of mixtures and advanced predictive models for property estimation. Thermal behaviour, fatigue performance, and engineering applications of MMCs in advanced structural and functional components.

**Unit IV**

**Ceramic Matrix Composites (CMC):** Engineering ceramics and their mechanical and fracture behaviour; classification and applications of ceramic matrix composites (CMCs). Processing techniques including Chemical Vapour Infiltration (CVI), Polymer Infiltration and Pyrolysis (PIP), Hot Isostatic Pressing (HIP), Cold Isostatic Pressing (CIP), Spark Plasma Sintering, microwave sintering, and additive manufacturing. Carbon–carbon composites, thermal shock resistance, oxidation behaviour, and ultra-high temperature applications of ceramic matrix composite systems.

**Unit V**

**Advanced Characterization:** Advanced characterization techniques for composite materials including cure and thermal analysis using Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA), and Dynamic Mechanical Analysis (DMA). Mechanical testing methods such as tensile, compression, fatigue, creep, and compression-after-impact testing. Environmental durability studies and life prediction of composites. Non-destructive evaluation techniques including ultrasonic testing, acoustic emission, radiography, and thermography. Microstructural characterization using SEM, TEM, and XRD.

**Suggested Readings:**

1. K. K. Chawla, *Composite Materials: Science and Engineering*, 2nd ed. New York, NY, USA: Springer, 2001.
2. A. B. Strong, *Fundamentals of Composite Manufacturing: Materials, Methods and Applications*. Dearborn, MI, USA: Society of Manufacturing Engineers, 1989.
3. F. L. Matthews and R. D. Rawlings, *Composite Materials: Engineering and Science*, 1st ed. London, U.K.: Chapman & Hall, 1994.
4. T. W. Clyne and P. J. Withers, *An Introduction to Metal Matrix Composites*. Cambridge, U.K.: Cambridge University Press, 1993.
5. R. F. Gibson, *Principles of Composite Material Mechanics*, 3rd ed. Boca Raton, FL, USA: CRC Press, 2016.
6. L. J. Broutman and R. M. Krock, *Modern Composite Materials*. Reading, MA, USA: Addison-Wesley,1967.