

# **Mechanical Engineering** **Research Methodology**

## **Section I**

**(50% Part of Entrance Examination for Ph.D. Admission)**

### **AN INTRODUCTION TO RESEARCH METHODOLOGY:**

Meaning, Objectives & Motivation of Research, Types of Research, Research Process, Identifying and Defining the Research Problem, Literature survey /review and its importance, Ethical aspects, IPR issues like patenting, copyrights etc.

### **CONCEPTUALISING A RESEARCH DESIGN:**

Need for Research Design, Features of a Good Design, Important Concepts Relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Sampling Design, Implications of a Sample Design, Criteria of Selecting a Sampling Procedure, Different Types of Sample Designs.

### **DATA COLLECTION, PROCESSING AND ANALYSIS:**

Measurement in Research, Measurement Scales, Tests of Sound Measurement, Scaling, Scale Classification Bases, Important Scaling Techniques, Scale Construction Techniques, Different Methods of Data Collection, Difference between Questionnaires and Schedules, Collection of Secondary Data, Processing Operations, Elements/Types of Analysis, Data Processing Operations, Elements of Analysis, Statistics in Research, Measures of Dispersion, Measures of Skewness, Regression Analysis, Correlation, Sampling Fundamentals.

### **HYPOTHESIS:**

Introduction to Hypothesis, Procedure for Hypothesis Testing, Parametric and nonparametric Hypothesis test, testing of hypothesis using various tests like Analysis of Variance and Covariance, Chi square test, Multivariate analysis.

### **INTERPRETATION AND REPORT WRITING**

Research Report, Mechanics of Writing a Research Report, Research Paper writing, Layout of research paper, Paper publishing, Impact factor, Citation & Acknowledgements.

---

### **BOOKS RECOMMENDED:**

Research Methodology — C.R.Kothari

Business Research Methods — Donald Cooper & Pamela Schindler, TMGH, 9th edition Business Research

Methods — Alan Bryman & Emma Bell, Oxford University Press.

## Section II (Subject specific Syllabus) Mechanical Engineering

Remaining 50% shall be based on Subject Specific as mentioned below

### A. Design Engineering

#### Mathematical Modeling and Design Optimization

Concept of modeling, Types of Modeling, Classification of mathematical modeling, Use of Analogy, Data consideration and Testing of Models, Modeling of dynamic systems with differential equations, simulation of data in the form of mathematical equations, Linear-Non-linear equations, determining the Unknowns of Equations using Least Square Criterion, Process of Simulation, Steps and Features of Simulation Experiments and their Validation.

#### Advanced Design Engineering

Analysis of variance, factorial design and regression analysis, Reliability theory, design for reliability, Hazard analysis and fault tree analysis. Fatigue strength, factors affecting fatigue behavior, Cumulative fatigue damage, fatigue under complex stresses, mechanism of creep of material at high temperature, Exponential creep law, hyperbolic sine creep law, stress relaxation, bending etc. Optimization: Introduction, multivariable search methods, linear & geometric programming, structural and shape optimization and simplex method. Design for brittle fracture, Design for fatigue failure, Design for different machining process, assembly & safety etc.

#### Advanced Engineering Materials

Metals and alloys: ferrous and non-ferrous, plastics and polymers, ceramics and composites. Heat treatment of ferrous and non-ferrous alloys for modification of structure and properties, smart materials, shape memory alloys, Non Metallic Materials- Polymer materials, formation of polymer structures, production techniques of fibers, foams, adhesives and coatings. Composites: Fibers-glass, boron, carbon, organic, ceramic and metallic fibers-matrix materials polymers, metals and ceramics. Selection of Materials: selection for mechanical properties, strength, toughness, fatigue and creep.

#### Advanced Theory of Vibrations

Fundamentals of free and forced vibrations, Single and two degree of freedom systems, Vibration absorbers and isolators, Multi degree freedom, Vibration of continuous systems, Experimental methods in vibration analysis, Free and Forced Vibration tests. Non-Linear Vibrations: Sources of nonlinearity, Qualitative analysis of nonlinear systems. Random Vibrations: Random phenomena, Time averaging and expected value, Frequency response function, Probability distribution, Correlation, Power spectrum and power spectral density, Fourier transforms, FTs and response.

### B. Heat Power Engineering

#### Advanced Fluid Mechanics

Concept of Continuum & Fluid, Mass conservation in differential and integral forms, Laminar and Turbulent flows, Viscous flow at different Reynolds number-wake frequency, Navier-Stokes Equations, fully developed flow in channel, pipe, flow between concentric rotating cylinders, Boundary Layers, hydrodynamic stability, velocity profile over a flat plate and in pipes. Turbulent Shear Flows: Equations for free shear layers: mixing layer, plane and axisymmetric jet, wake. Turbulent energy equation, two equation model(k-epsilon), Large Eddy Simulation, Various Turbulent Models, 2-dimensional flows (subsonic and supersonic) past slender bodies, compressible boundary layers.

#### Advanced Thermodynamics and Combustion

General Relations involving internal energy, enthalpy and entropy, Thermodynamics Relations involving specific heat, Joule Thomson Coefficient, Developing Tables of Thermodynamics properties from experimental data. Equation of state for real gases, derivation of ideal gas laws from kinetic theory, statistical thermodynamics, Mixtures and Solutions. Combustion basics and Combustion Theories, combustion in closed and open systems, application to boiler, gas turbine combustors and rocket motors.

## **Advanced Heat Transfer**

Differential Equation of Heat conduction in Cartesian conduction Cylindrical and Spherical coordinates of isotropic and anisotropic materials, recent advances in Fins, their material and Heat Transfer enhancement Technique, Mathematical analysis of two-dimensional Heat Conduction, Lumped Heat Capacity system, free convection from vertical planes and cylinders, Horizontal plates and cylinders, inclined surface. Radiation mechanism, properties, Shape factor, Shields, Radiation heat exchange between non-black bodies. Radiation network for an absorbing and Transmitting, Reflecting and absorbing media. Condensation and boiling enhancement techniques, heat transfer correlations for pool and flow boiling.

## **Design of Heat Transfer Equipment**

Design of Shell and Tube Heat Exchangers, Boiler furnace design, Design of Steam Condenser and evaporative condensers, Design of surface and evaporative condensers, cooling tower, performance characteristics.

## **C. Production Engineering**

### **Advanced Manufacturing Processes**

Forging, rolling, extrusion, wire drawing, sheet metal processes, Types of prototypes, principles and advantages and different types of generative manufacturing processes, viz. stereo lithography, FDM, SLS etc. non-conventional machining processes, Principle and theory of material removal. Process parameters, advantages, limitations and applications of ultrasonic machining, laser beam machining and electrochemical machining.

### **Metal Forming Technology**

Mechanics of metal working, stress strain relationship, yield criteria, Equilibrium in Cartesian, cylindrical and spherical coordinates, Slab method and lower and upper bond methods for load, their significance in investigating and modeling of metal working operations; plastic work, work hardening, strain rate and temperature, deformation zone geometry, formability, forming limit diagrams. Forging die design: Design principles, Preform design considerations, Die materials. Theories of cold rolling, hot rolling, torque and power, Roll pass design. Analysis of the extrusion process, cold Extrusion and cold forming, hydrostatic extrusion, extrusion of tubing, Production of seamless pipe and tubing.

### **Advanced Casting Technology**

Review of conventional method of casting and pattern design, pattern and die design considerations,, advanced materials for patterns and dies - selection and applications, High pressure molding technology, flask less molding technology, magnetic molding, Process parameters for Die casting gravity, pressure and low pressure, Centrifugal casting, Vacuum casting, Investment casting, Squeeze casting; Melting technologies for steels, grey C.I., S.G. iron and compacted graphite iron, Al-Si alloys, Magnesium and Titanium based alloys; Casting defects and their classification, rejection analysis, remedial measures.

### **Production, Operation and Project Management**

Relation between production and operations and other functions, products and services, impact of information technology on productions and operations management, Business strategy- competitive priorities, developing operations strategy, productivity and competitiveness. Traditional and concurrent product design, design for manufacture, service, assembly, Design of services, Quality of design, cost of quality, Forecasting Methods, Production Planning, Scheduling, Theory of Constraints, Foundations of Project Management, Project Life Cycle, Project Environment, Project Selection, Project Proposal, Project Scope, Work Breakdown Structure, Network Scheduling, Critical Path Method, Program Evaluation and Review Technique, Planning and Scheduling of Activity Networks, Assumptions in PERT Modeling, Time-cost Trade-offs Scheduling with limited resources, Resource Planning, Resource Allocation, Project Schedule Compression, Crashing, Estimation of Project Costs, Earned Value Analysis, Monitoring Project Progress, Project Appraisal and Selection, Recent Trends in Project Management.