M.Tech – Machine Design

(CR-24 IInd YEAR COURSE STRUCTURE & SYLLABUS)

III Semester

S.No.	Code	Subject		L	T	P	Credits
1	**Programme Elective – V*** **MD 301**	MD 3011	Industrial Robotics	3	0	0	3
		MD 3012	Advanced Optimization Techniques				
		MD 3013	Additive Manufacturing				
		MD 3014	Mechanics of Composite Materials				
		MD 3015	Vehicle Dynamics				
2	**Open Elective**	Should register for courses offered by other departments		3	0	0	3
3	**Dissertation**	Dissertation Phase -I		0	0	20	10
Total							**16**

* Students going for Industrial Project/ Thesis will complete programme elective and open elective courses through MOOCs

IV Semester

S.No.	Code	Subject	L	T	P	Credits
1	Dissertation	Dissertation Phase -II	0	0	32	16
Total						**16**

Courses offered by Mechanical Engineering Department to other departments as Open electives.

S.No.	Code	Subject	L	T	P	Credits
1	**MD 3021**	Industrial Robotics	3	0	0	3
2	**MD 3022**	Operations Research	3	0	0	3
3	**MD 3023**	Additive Manufacturing	3	0	0	3
4	**MD 3024**	Experimental Techniques and Data Analysis	3	0	0	3

II Year III Semester

L	T	P	C
3	0	0	3

INDUSTRIAL ROBOTICS
(Programme Elective - V)

UNIT - I

INTRODUCTION: Automation and Robotics, Robot anatomy, robot configuration, motions joint notation scheme, work volume, robot drive systems, control systems and dynamic performance, precision of movement.

CONTROL SYSTEM AND COMPONENTS: basic concepts and motion controllers, control system analysis, robot actuation and feedback components.

SENSORS: Desirable features, tactile, proximity and range sensors, uses sensors in robotics. Positions sensors, velocity sensors, actuators, power transmission systems

UNIT - II

MOTION ANALYSIS AND CONTROL: Manipulator kinematics, position representation, forward and inverse transformations, homogeneous transformations, manipulator path control, robot arm dynamics, configuration of a robot controller. Robot joint control design.

UNIT - III

END EFFECTORS: Grippers-types, operation, mechanism, force analysis, tools as end effectors consideration in gripper selection and design.

MACHINE VISION: Functions, Sensing and Digitizing-imaging devices, Lighting techniques, Analog to digital single conversion, image storage: Image processing and Analysis-image data reduction, Segmentation, feature extraction, Object recognition. Training the vision system, Robotic application.

UNIT - IV

ROBOT PROGRAMMING: Lead through programming, Robot program as a path in space, Motion interpolation, WAIT, SIGNAL AND DELAY commands, Branching, capabilities and Limitations of lead through methods.
ROBOT LANGUAGES: Textual robot Languages, Generations of robot programming languages, Robot language structures, Elements and function.

UNIT - V

ROBOT CELL DESGIN AND CONTROL: Robot cell layouts-Robot centered cell, In-line robot cell, Considerations in work design, Work and control, Inter locks, Error detection, Work cell controller.

ROBOT APPLICATION: Material transfer, Machine loading/unloading, Processing operation, Assembly and Inspection, Future Application.

TEXT BOOKS:

1. Industrial Robotics / Groover M P /Pearson Edu.
2. Introduction to Robotic Mechanics and Control by JJ Craig, Pearson, 3rd edition.

REFERENCES:

1 Robotics / Fu K S/ McGraw Hill.
2 Robotic Engineering / Richard D. Klafter, Prentice Hall
3 Robot Analysis and Intelligence / Asada and Slotine / Wiley Inter-Science.
4 Robot Dynamics & Control – Mark W. Spong and M. Vidyasagar / John Wiley
5 Introduction to Robotics by SK Saha, The McGrah Hill Company, 6th, 2012
6 Robotics and Control / Mittal R K & Nagrath I J / TMH

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Identify the components of industrial robots and apply knowledge of robot anatomy, configurations, drive and control systems.	L3
CO2	Apply the concepts of manipulator kinematics and transformations for analyzing robot motion and path control.	L3
CO3	Apply the principles of end effectors and machine vision systems for performing basic robotic operations.	L3
CO4	Develop basic robot programs using lead-through methods and robot programming languages.	L3
CO5	Apply the knowledge of robot cell layouts and control techniques to simple industrial applications such as material handling and inspection.	L3

II Year III Semester

L	T	P	C
3	0	0	3

ADVANCED OPTIMIZATION TECHNIQUES
(Programme Elective - V)

COURSE OBJECTIVES:

- To introduce the advanced optimization techniques such as classical optimization techniques, numerical optimization techniques and genetic algorithms.
- Learn the knowledge to formulate optimization problems

UNIT - I

Classical optimization techniques: Single variable optimization with and without constraints, multi – variable optimization without constraints, multi – variable optimization with constraints – method of Lagrange multipliers, Kuhn-Tucker conditions.

UNIT - II

Numerical methods for optimization: Nelder Mead's Simplex search method, Gradient of a function, Steepest descent method, Newton's method, types of penalty methods for handling constraints.

UNIT - III

Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA,

Multi-Objective GA: Pareto's analysis, Non-dominated front, multi – objective GA, Non-dominated sorted GA, convergence criterion, applications of multi-objective problems

UNIT – IV

Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.

UNIT V

Applications of Optimization in Design and Manufacturing systems: Some typical applications like optimization of path synthesis of a four-bar mechanism, minimization of weight of a cantilever beam and general optimization model of a machining process.

TEXT BOOKS:

1. Optimal design – JasbirArora, McGraw Hill (International) Publishers
2. Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers
3. Engineering Optimization – S.S.Rao, New Age Publishers

REFERENCES:

1. Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison- Wesley Publishers
2. Genetic Programming- Koza
3. Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publishers

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Understand and apply classical optimization techniques to solve single-variable and multi-variable optimization problems with and without constraints.	L3
CO2	Analyze numerical optimization methods such as Nelder Mead's Simplex search method, steepest descent, and Newton's method for solving optimization problems.	L4
CO3	Apply genetic algorithms (GA) for constrained and unconstrained optimization problems, and evaluate their performance in multi-objective optimization.	L3
CO4	Demonstrate the principles of genetic programming (GP) and its application in solving differential equations and optimization problems.	L3
CO5	Apply optimization techniques in design and manufacturing systems for practical problems like mechanism path synthesis, cantilever beam weight minimization, and machining process optimization.	L3

II Year III Semester

L	T	P	C
3	0	0	3

ADDITIVE MANUFACTURING
(Programme Elective - V)

UNIT I

Additive Manufacturing Process: Basic Principles of the Additive Manufacturing Process, Generation of Layer Information, Physical Principles for Layer Generation. Elements for Generating the Physical Layer, Classification of Additive Manufacturing Processes, Evaluation of the Theoretical Potentials of Rapid Prototyping Processes.

UNIT II

Machines for Rapid Prototyping: Overview of Polymerization: Stereolithography (SL), Sintering/Selective Sintering: Melting in the Powder Bed, Layer Laminate Manufacturing (LLM) and Three-Dimensional Printing (3DP).

UNIT III

Rapid Prototyping: Classification and Definition, Strategic Aspects for the Use of Prototypes, Applications of Rapid Prototyping in Industrial Product Development. Rapid Tooling: Classification and Definition of Terms, Properties of Additive Manufactured Tools, Indirect Rapid

UNIT IV

Tooling Processes: Molding Processes and Follow-up Processes, Indirect Methods for the Manufacture of Tools for Plastic Components, Indirect Methods for the Manufacture of Metal Components.

UNIT V

Direct Rapid Tooling Processes: Prototype Tooling: Tools Based on Plastic Rapid Prototyping Models and Methods, Metal Tools Based on Multilevel AM Processes, Direct Tooling: Tools Based on Metal Rapid Prototype Processes.

TEXT BOOKS:

1. Andreas Gebhardt Jan-Steffen Hötter, Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Hanser Publications, 6915 Valley Avenue, Cincinnati, Ohio.
2. Ian Gibson, David Rosen, Brent Stucker, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Second Edition, Springer New York Heidelberg Dordrecht London.

REFERENCES:

1. Liou L.W. and Liou F.W., "Rapid Prototyping and Engineering applications : A tool box for prototype development", CRC Press, 2007.
2. Kamrani A.K. and Nasr E.A., "Rapid Prototyping: Theory and practice", Springer, 2006. 3. Hilton P.D. and Jacobs P.F., "Rapid
3. Tooling: Technologies and Industrial Applications", CRC press, 2000.

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Understand the basic principles and classification of additive manufacturing processes, and evaluate the theoretical potentials of rapid prototyping techniques.	L2
CO2	Describe the various machines used for rapid prototyping, including stereolithography, selective sintering, and 3D printing technologies.	L2
CO3	Analyze the strategic aspects and applications of rapid prototyping in industrial product development and rapid tooling.	L4
CO4	Examine indirect rapid tooling methods for manufacturing plastic and metal components and understand their processes.	L4
CO5	Apply direct rapid tooling methods for producing prototype and metal tools using additive manufacturing technologies.	L3

II Year III Semester

L	T	P	C
3	0	0	3

MECHANICS OF COMPOSITE MATERIALS
(Programme Elective - V)

COURSE OBJECTIVES:

The objective for this course is to understand the mechanics of composite materials. This understanding will include concepts such as anisotropic material behavior strength theories, micro mechanics and the analysis of laminated composites. The students will undertake a design project involving application of fiber reinforced composites.

UNIT-I

Introduction to Composites, Classification, matrix materials, reinforced matrix of composites.

UNIT-II

Hooke's Law for a Two-Dimensional Angle Lamina, Engineering Constants of an Angle Lamina, Invariant Form of Stiffness and Compliance Matrices for an Angle Lamina Strength Failure Theories of an Angle Lamina : Maximum Stress Failure Theory Strength Ratio, Failure Envelopes, Maximum Strain Failure Theory ,Tsai–Hill Failure Theory, Tsai–Wu Failure Theory, Comparison of Experimental Results with Failure Theories. Hygrothermal Stresses and Strains in a Lamina: Hygrothermal Stress–Strain Relationships for a Unidirectional Lamina, Hygrothermal Stress–Strain Relationships for an Angle Lamina

UNIT-III

Macromechanical Analysis of a Lamina :Introduction ,Definitions: Stress, Strain ,Elastic Moduli,Strain Energy. Hooke's Law for Different Types of Materials, Hooke's Law for a Two- Dimensional Unidirectional Lamina, Plane Stress Assumption, Reduction of Hooke's Law in Three Dimensions to Two Dimensions, Relationship of Compliance and Stiffness Matrix to Engineering Elastic Constants of a Lamina,

UNIT-IV

Micromechanical Analysis of a Lamina :Introduction, Volume and Mass Fractions, Density, and Void Content, Evaluation of the Four Elastic Moduli, Strength of Materials Approach, Semi- Empirical Models ,Elasticity Approach, Elastic Moduli of Lamina with Transversely Isotropic Fibers, Ultimate Strengths of a Unidirectional Lamina, Coefficients of Thermal Expansion, Coefficients of Moisture Expansion

Macromechanical Analysis of Laminates: Introduction , Laminate Code , Stress–Strain Relations for a Laminate, In-Plane and Flexural Modulus of a Laminate , Hygrothermal Effects in a Laminate, Warpage of Laminates,hybrid laminates

UNIT-V

Failure, Analysis, and Design of Laminates: Introduction , Special Cases of Laminates, Failure Criterion for a Laminate, Design of a Laminated Composite, static analysis of laminated plates

TEXT BOOKS:

1. Engineering Mechanics of Composite Materials by Isaac and M Daniel, Oxford University Press, 1994.
2. B. D. Agarwal and L. J. Broutman, Analysis and performance of fibre Composites, Wiley- Interscience, New York, 1980.
3. Mechanics of Composite Materials, Second Edition (Mechanical Engineering), By Autar K. Kaw ,Publisher: CRC

REFERENCES:

1. R. M. Jones, Mechanics of Composite Materials, McGraw Hill Company, New York, 1975.
2. L. R. Calcote, Analysis of Laminated Composite Structures, Van NostrandRainfold, New York, 1969.

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Understand the classification and basic concepts of composite materials, including matrix materials and fiber reinforcements.	L2
CO2	Apply Hooke's Law and strength failure theories to analyze the behavior of an angle lamina under different stress conditions.	L3
CO3	Perform macromechanical analysis of a lamina, including stress-strain relationships, elastic moduli, and strain energy concepts.	L3
CO4	Evaluate the micromechanical properties of a lamina using semi-empirical and elasticity models, and analyze thermal and moisture expansion effects.	L4
CO5	Analyze and design laminated composites, considering failure theories, static analysis, and the effects of hygrothermal conditions on laminate performance.	L4

L	T	P	C
3	0	0	3

II Year III Semester

VEHICLE DYNAMICS
(Programme Elective - V)

UNIT-I

Introduction to Vehicle Dynamics: Various kinds of vehicles, Motions, Mathematical modelling methods, Multibody system approach, Lagrangian formulations, Methods of investigations, Stability concepts.

UNIT-II

Mechanics of pneumatic tyres: Tyre construction, SAE recommended practice, Tyre forces and moments, Rolling resistance of tyres, Tractive effort and longitudinal slip, Cornering properties of tyres, Performance of tyre traction on dry and wet surfaces, Ride properties of tyres.

UNIT-III

Performance characteristics of road vehicle: Equation of motion and maximum tractive effort, Aerodynamic forces and moments, Vehicle power plant and transmission characteristics, Prediction of vehicle performance, Operating fuel economy, Braking performance.

UNIT-IV

Handling and stability characteristics of road vehicles: Steering geometry, Steady state handling characteristics, Steady state response to steering input, Testing of handling characteristics, Transient response characteristics, Directional stability, Effects of tyre factors, Mass distribution and engine location on stability of handling.

UNIT-V

Vehicle ride characteristics: Human response to vibration, Vehicle ride models, Introduction to random vibration - 1) Road surface profile as a random function, 2) Frequency response function, 3) Evaluation of vehicle vertical vibration in relation to ride comfort criteria, 4) Active and semi active systems, 5) Optimum design for ride comfort and road holding.

TEXT BOOKS:

1. Theory of Ground Vehicles by Wong, J.Y., John Wiley and Sons, NY, 1993.

REFERENCES:

1. Fundamentals of Vehicle Dynamics by Gillespie, T.D., SAE Publication, Warrendal, USA, 1992.
2. Tyres, Suspension and Handling by Dixon, J.C., SAE Publication, Warrendal, USA and Arnold Publication, London, 1997.

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Understand the principles of vehicle dynamics, including mathematical modelling, multibody system approaches, and stability concepts.	L2
CO2	Analyze the mechanics of pneumatic tyres, including construction, forces, moments, rolling resistance, and performance characteristics.	L4
CO3	Apply vehicle performance characteristics to analyze equations of motion, tractive effort, aerodynamic forces, and fuel economy.	L3
CO4	Examine handling and stability characteristics of vehicles, including steering geometry, transient response, and directional stability.	L4
CO5	Evaluate vehicle ride characteristics and apply ride comfort criteria, including the use of random vibration analysis and active/semi-active systems.	L4

II Year IV Semester

L	T	P	C
0	0	32	16

DISSERTATION
(Phase II)

II Year III Semester

L	T	P	C
0	0	20	10

DISSERTATION (Phase I)

L	T	P	C
3	0	0	3

II Year III Semester

INDUSTRIAL ROBOTICS
(Open Elective)

UNIT - I

INTRODUCTION: Automation and Robotics, Robot anatomy, robot configuration, motions joint notation scheme, work volume, robot drive systems, control systems and dynamic performance, precision of movement.

CONTROL SYSTEM AND COMPONENTS: basic concepts and motion controllers, control system analysis, robot actuation and feedback components.

SENSORS: Desirable features, tactile, proximity and range sensors, uses sensors in robotics. Positions sensors, velocity sensors, actuators, power transmission systems

UNIT - II

MOTION ANALYSIS AND CONTROL: Manipulator kinematics, position representation, forward and inverse transformations, homogeneous transformations, manipulator path control, robot arm dynamics, configuration of a robot controller. Robot joint control design.

UNIT - III

END EFFECTORS: Grippers-types, operation, mechanism, force analysis, tools as end effectors consideration in gripper selection and design.

MACHINE VISION: Functions, Sensing and Digitizing-imaging devices, Lighting techniques, Analog to digital single conversion, image storage: Image processing and Analysis-image data reduction, Segmentation, feature extraction, Object recognition. Training the vision system, Robotic application.

UNIT - IV

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ROBOT LANGUAGES: Textual robot Languages, Generations of robot programming languages, Robot language structures, Elements and function.

UNIT - V

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1 Robotics / Fu K S/ McGraw Hill.
2 Robotic Engineering / Richard D. Klafter, Prentice Hall
3 Robot Analysis and Intelligence / Asada and Slotine / Wiley Inter-Science.
4 Robot Dynamics & Control – Mark W. Spong and M. Vidyasagar / John Wiley
5 Introduction to Robotics by SK Saha, The McGrah Hill Company, 6th, 2012
6 Robotics and Control / Mittal R K & Nagrath I J / TMH

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Identify the components of industrial robots and apply knowledge of robot anatomy, configurations, drive and control systems.	L3
CO2	Apply the concepts of manipulator kinematics and transformations for analyzing robot motion and path control.	L3
CO3	Apply the principles of end effectors and machine vision systems for performing basic robotic operations.	L3
CO4	Develop basic robot programs using lead-through methods and robot programming languages.	L3
CO5	Apply the knowledge of robot cell layouts and control techniques to simple industrial applications such as material handling and inspection.	L3

L	T	P	C
3	0	0	3

II Year III Semester

OPERATIONS RESEARCH
(Open Elective)

UNIT I:
Optimization Techniques, Model Formulation, models, General L.R Formulation, Simplex Techniques, Sensitivity Analysis, Inventory Control Models

UNIT II
Formulation of a LPP - Graphical solution revised simplex method - duality theory - dual simplex method - sensitivity analysis - parametric programming

UNIT III:
Nonlinear programming problem - Kuhn-Tucker conditions min cost flow problem - max flow problem - CPM/PERT

UNIT IV
Scheduling and sequencing - single server and multiple server models - deterministic inventory models - Probabilistic inventory control models - Geometric Programming.

UNIT V
Competitive Models,Single and Multi-channel Problems, Sequencing Models, Dynamic Programming, Flow in Networks, Elementary Graph Theory, Game Theory Simulation

TEXT BOOKS:
1. H.A. Taha, Operations Research, An Introduction, PHI, 2008
2. H.M. Wagner, Principles of Operations Research, PHI, Delhi, 1982.

REFERENCES:
1. J.C. Pant, Introduction to Optimization: Operations Research, Jain Brothers, Delhi, 2008
2. Hitler Libermann Operations Research: McGraw Hill Pub. 2009
3. Pannerselvam, Operations Research: Prentice Hall of India 2010
4. Harvey M Wagner, Principles of Operations Research: Prentice Hall of India 2010

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Understand the basic optimization techniques, model formulations, and sensitivity analysis in linear programming and inventory control.	L2
CO2	Apply linear programming techniques including graphical solution, simplex method, and duality theory to solve optimization problems.	L3
CO3	Analyze and solve nonlinear programming problems using Kuhn-Tucker conditions and apply CPM/PERT techniques for project management.	L4
CO4	Evaluate scheduling, sequencing, and inventory models, and apply probabilistic and deterministic models for inventory control.	L4
CO5	Apply competitive models, dynamic programming, game theory, and simulation methods to solve real-world problems in operations research.	L3

II Year III Semester

L	T	P	C
3	0	0	3

ADDITIVE MANUFACTURING
(Open Elective)

UNIT I

Additive Manufacturing Process: Basic Principles of the Additive Manufacturing Process, Generation of Layer Information, Physical Principles for Layer Generation. Elements for Generating the Physical Layer, Classification of Additive Manufacturing Processes, Evaluation of the Theoretical Potentials of Rapid Prototyping Processes.

UNIT II

Machines for Rapid Prototyping: Overview of Polymerization: Stereolithography (SL), Sintering/Selective Sintering: Melting in the Powder Bed, Layer Laminate Manufacturing (LLM) and Three-Dimensional Printing (3DP).

UNIT III

Rapid Prototyping: Classification and Definition, Strategic Aspects for the Use of Prototypes, Applications of Rapid Prototyping in Industrial Product Development. Rapid Tooling: Classification and Definition of Terms, Properties of Additive Manufactured Tools, Indirect Rapid

UNIT IV

Tooling Processes: Molding Processes and Follow-up Processes, Indirect Methods for the Manufacture of Tools for Plastic Components, Indirect Methods for the Manufacture of Metal Components.

UNIT V

Direct Rapid Tooling Processes: Prototype Tooling: Tools Based on Plastic Rapid Prototyping Models and Methods, Metal Tools Based on Multilevel AM Processes, Direct Tooling: Tools Based on Metal Rapid Prototype Processes.

TEXT BOOKS:

1. Andreas Gebhardt Jan-Steffen Hötter, Additive Manufacturing: 3D Printing for Prototyping and Manufacturing, Hanser Publications, 6915 Valley Avenue, Cincinnati, Ohio.
2. Ian Gibson, David Rosen, Brent Stucker, Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Second Edition, Springer New York Heidelberg Dordrecht London.

REFERENCES:

1. Liou L.W. and Liou F.W., “Rapid Prototyping and Engineering applications : A tool box for prototype development”, CRC Press, 2007.
2. Kamrani A.K. and Nasr E.A., “Rapid Prototyping: Theory and practice”, Springer, 2006. 3. Hilton P.D. and Jacobs P.F., “Rapid
3. Tooling: Technologies and Industrial Applications”, CRC press, 2000.

Course Outcomes:

COs	Statements	Bloom’s Level
CO1	Understand the basic principles and classification of additive manufacturing processes, and evaluate the theoretical potentials of rapid prototyping techniques.	L2
CO2	Describe the various machines used for rapid prototyping, including stereolithography, selective sintering, and 3D printing technologies.	L2
CO3	Analyze the strategic aspects and applications of rapid prototyping in industrial product development and rapid tooling.	L4
CO4	Examine indirect rapid tooling methods for manufacturing plastic and metal components and understand their processes.	L4
CO5	Apply direct rapid tooling methods for producing prototype and metal tools using additive manufacturing technologies.	L3

II Year III Semester

L	T	P	C
3	0	0	3

Experimental Techniques and Data Analysis
(Open Elective)

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 photoelasticity, Holography, interferometer, Moir techniques, strain gauge rosettes.

UNIT-II

Temperature Measurement: Circuits and instrumentation for different transducers viz., bimetallic, expanding fluid, electrical resistance, thermister, thermocouples, pyrometers.

Flow Measurement: Transducers for flow measurements of Non-compressible fluids, Obstruction and drag methods. Vortex shredding flow meters. Ultrasonic, Laser Dopler and Hotwire anemometer. Flow visualization techniques, Shadow graphs, Schilieren photography. Interferometer.

UNIT-III

Metallurgical Studies: Optical and electron microscopy, X-ray diffraction, Brag's Law and its application for studying crystal structure and residual stresses. Electron spectroscopy, electron microprobe.

Surface Measurement: Micro hardness, roughness, accuracy of dimensions and forms. 3-D Co- ordinate measuring machines.

UNIT-IV

Experiment design & data analysis: Statistical methods, Randomised block design, Latin and orthogonal squares, factorial design. Replication and randomization.

Data Analysis: Deterministic and random data, uncertainty analysis, test of significance: Chi- square, student's 't' test. Regression modeling, direct and interaction effects. ANOVA, F-test. Time Series analysis, Autocorrelation and autoregressive modeling.

UNIT-V

Taguchi Methods: Experimental 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. Concepts of loss function and its application.

TEXT BOOKS:

1. Jack Philip Holman, Experimental Methods for Engineers, 7th edition, McGraw-Hill, 2001
2. V. C. Venkatesh, H. Chandrasekaran, Experimental Techniques in Metal Cutting, Eastern economy edition, Prentice-Hall of India, 1987

REFERENCES:

1. George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, Greta M. Ljung, Time Series Analysis: Forecasting and Control, 5th Edition, John Wiley & Sons, 2015
2. Richard C. Dove, Paul H. Adams, Experimental stress analysis and motion measurement: theory, instruments and circuits, techniques, C. E. Merrill Books, 1964
3. Bagchi Tapan P, Taguchi Methods Explained: Practical Steps to Robust Design, Prentice-Hall (India), 1993.

Course Outcomes:

COs	Statements	Bloom's Level
CO1	Understand the principles and characteristics of measurement techniques in cutting force analysis, including strain gauges and piezoelectric transducers.	L2
CO2	Apply temperature and flow measurement methods, utilizing various transducers for accurate data collection in experimentations.	L3
CO3	Analyze metallurgical structures using optical and electron microscopy, and understand the application of Bragg's Law for stress analysis.	L4
CO4	Evaluate experimental designs including statistical methods for data analysis, and apply techniques such as ANOVA and regression modeling.	L4
CO5	Apply Taguchi Methods for experimental design and optimization, focusing on the evaluation of response levels and noise factors.	L3