M.TECH –MANUFACTURING ENGINEERING

Department of Mechanical Engineering

This program focuses on the requirements of the manufacturing industry embracing the areas of production, planning and control, design, materials, processes and quality control. The curriculum has been framed drawing course contents from traditional fields such as materials and processes, manufacturing engineering, industrial engineering, and management. The syllabus for various courses has been designed in general to introduce the application of analytical and quantitative methods in manufacturing and to train the students to develop skills in the utilization of the modern tools such as simulation, optimization, statistical data analysis, and finite element analysis. During the course of study, the students will acquire knowledge and skills to solve practical problems encountered in manufacturing.

Curriculum

First Semester

Course Code	Type	Course	L T P	Cr
16MA612	FC	Stochastic Process and Partial Differential Equations	3 0 1	4
16ME600	FC	Advances in Materials Science	3 0 1	4
16ME601	FC	Analysis of Machining Processes	3 0 0	3
16ME602	FC	Theory of Plasticity and Metal Forming	3 0 0	3
16ME650	SC	Manufacturing Automation	3 0 1	4
16ME661	SC	Manufacturing Engineering Lab I	0 0 1	1
16HU601	HU	Cultural Education*		P/F
			Credits	19

*Non-credit course

Second Semester

Course Code	Type	Course	L T P	Cr
16ME651	SC	Advanced Casting Technology	3 0 0	3
16ME652	SC	Lean Manufacturing	3 0 0	3
16ME653	SC	Advances in Manufacturing Technology and Metrology	3 0 0	3
	E	Elective I	3 0 0	3
	E	Elective II	3 0 0	3
16ME662	SC	Manufacturing Engineering Lab II	0 0 1	1
16ME663	SC	Manufacturing Engineering Lab III	0 0 1	1
16EN600	HU	Technical Writing*		P/F
16ME664	SC	Research Methodology	0 0 1	1
			Credits	18

*Non-credit course

Third Semester

Course Code	Type	Course	L T P	Cr
16ME654	SC	Production and Operations Management	3 0 0	3
	E	Elective III	3 0 0	3
16ME798	P	Dissertation		10
			Credits	16

Fourth Semester

Course Code	Type	Course	L T P	Cr
16ME799	P	Dissertation		12
			Credits	12

Total credits: 65

List of Courses

Foundation Core

Course Code	Type	Course	L T P	Cr
16MA612	FC	Stochastic Process and Partial Differential Equations	3 0 1	4
16ME600	FC	Advances in Materials Science	3 0 1	4
16ME601	FC	Analysis of Machining Processes	3 0 0	3
16ME602	FC	Theory of Plasticity and Metal Forming	3 0 0	3

Subject Core

Course Code	Course	L T P	Cr
16ME650	Manufacturing Automation	3 0 1	4
16ME651	Advanced Casting Technology	3 0 0	3
16ME652	Lean Manufacturing	3 0 0	3
16ME653	Advances in Manufacturing Technology	3 0 0	3
16ME654	Production and Operations Management	3 0 0	3
16ME661	Manufacturing Engineering Lab I	0 0 1	1
16ME662	Manufacturing Engineering Lab II	0 0 1	1
16ME663	Manufacturing Engineering Lab III	0 0 1	1
16EN600	Technical Writing	0 0 1	1
16ME664	Research Methodology	0 0 1	1

Electives

Course Code	Course	L	T	P	Cr
16ED654	Optimization Techniques in Engineering	2	0	1	3
16ME701	Finite Element Methods	3	0	0	3
16ME702	Surface Engineering	3	0	0	3
16ME703	Design of Experiments	3	0	0	3
16ME704	Advanced Welding Technology	3	0	0	3
16ME705	Embedded Systems	3	0	0	3
16ME706	Logistics and Supply Chain Management	3	0	0	3
16ME707	Composite Materials and Processing	3	0	0	3
16ME708	Product Lifecycle Management	3	0	0	3
16ME709	Tool Engineering and Design	3	0	0	3
16ME710	Advances in Process Technology	3	0	0	3
16ME711	Reliability Engineering	3	0	0	3
16ME712	Computer Aided Product Development	3	0	0	3
16ME713	Quality Engineering	3	0	0	3
16ME714	Additive Manufacturing	3	0	0	3

Project Work

Course Code	Course	L	T	P	Cr
16ME798	Dissertation				10
16ME799	Dissertation				12

16MA612 STOCHASTIC PROCESS AND PARTIAL DIFFERENTIAL EQUATIONS 3-0-1-4

Review of Probability Concepts and Random Variables
Random Processes: General concepts and definitions-Stationarity in random process-autocorrelation and properties-Poisson points, Poisson and Gaussian processes-Spectrum estimation- Ergodicity and mean Ergodic theorem-Power spectral density and properties. Markov processes –Markov Chains – Transition Probability matrix- Classification of states-Limiting Distributions.
Analysis of Variance: One way and two way analysis of variance. Fixed and random efforts models-Multiple comparison test for one way analysis. Completely randomized block design- Latin square design – Two factor factorial design – Model with main and interaction efforts and analysis.
Partial Differential Equations: Basic definitions. Model Equations: Elliptic, Parabolic and Hyperbolic PDEs. Solving PDEs Numerically - Elliptic, Parabolic and Hyperbolic Equations. Finite Element Method.
Matlab: Problems in Analysis of Variance and PDE

TEXT BOOKS / REFERENCES:

1. A. Papoulis and Unnikrishna Pillai, "*Probability, Random Variables and Stochastic Processes*", Fourth Edition, McGraw Hill, 2002.
2. Ravichandran, J. *Probability and Statistics for Engineers*, First Edition, Wiley India, 2012.
3. Douglas C. Montgomery and George C.Runger, *Applied Statistics and Probability for Engineers*, (2005) John Wiley and Sons Inc.
4. Lawrence C. Evans, "*Partial Differential Equations"*, American Mathematical Society, 2010.
5. Gilles Aubert, Pierre Kornprobst, *Mathematical Problems in Image Processing: Partial Differential Equations"*, Springer, 2006.

16ME600 ADVANCES IN MATERIALS SCIENCE 3-0-1-4

Interfaces: Classification, geometry and thermodynamics of interfaces. Coherent and non-coherent boundaries. Free energy of interfaces. Equilibrium shapes of surfaces.
Solidification: Thermodynamics of homogeneous and heterogeneous nucleation and kinetics of growth. Interface morphologies. Role of thermal gradient and growth rate. Derivation of non-equilibrium freezing equation. Treatment of segregation. Nucleation in the solid state: Classical treatment and analytical formulation. Contribution of strain energy. Modes of nucleation. Diffusion in Solid State: Diffusion equations for steady state and transient conditions. Analytical solutions of diffusion equation for simple, practical problems. Strengthening methods: Principles, types of second phases, process sequence, controlling factors. Quench hardening and tempering. Precipitation hardening. Maraging. Spinodal hardening. Dispersion hardening-metal matrix composites, types of matrices and reinforcements. Hardening Methods for Al, Cu, Mg, Fe, Ni, Co and Ti

alloys. Recent advances in materials development-Entropy alloys: Functionally gradient materials, Shape memory alloys. Principles, properties and applications. Codes, Standards and Case Studies. Materials characterization techniques.

TEXT BOOKS/ REFERENCES:

1. Verhoeven, J. D., *"Fundamentals of Physical Metallurgy"*, John Wiley and Sons, 1975.
2. Sinha, A. K., *"Physical Metallurgy Handbook"*, McGraw-Hill, 2002.
3. Shewmon, P., *"Diffusion in Solids, Minerals, Metals"*, Materials Society, 1998.
4. Schwartz, M., *"New Materials, Processes, and Methods Technology"*, Taylor and Francis, 2006.

16ME601 ANALYSIS OF MACHINING PROCESSES 3-0-0-3

Mechanics of machining: Introduction, Mechanism of material removal- Chip formation. Force components, empirical force models, shear plane and finite element models for chip formation. Friction in metal cutting- stress distribution on tool face. Measurement of shear plane angle. Shear stress, strain and strain rate. Specific energies and material stress levels in machining. Forces in turning, drilling, milling and grinding. Force Measurement using dynamometers.

Thermal aspects: Thermal modeling- analytical models for steady-state temperatures, numerical models, temperatures in interrupted cutting, Temperature measurement.

Tool wear- mechanisms and measurement - work piece and tool condition monitoring system- monitoring techniques - surface finish and its measurement

Machining Dynamics- types of machine tool vibration -vibration analysis methods- chatter prediction- vibration control.

Process Modelling and simulation of Manufacturing Processes: turning, milling, drilling and grinding.

High-speed machining-tooling requirements- dynamics- machining of hard materials- advanced tool materials.

Codes, Standards and Case Studies.

TEXT BOOKS/ REFERENCES:

1. David A. Stephenson and John S. Agapiou*, "Metal Cutting Theory and Practice"*, CRC Press, 2005.
2. Milton C.Shaw, *"Metal Cutting Principles"*, Oxford University Press, 2006.
3. Childs, T. H. C., Maekawa, K., Obikawa, T., and Yaman. Y., *"Metal Machining: Theory and Apllications"*, Anrold Publishers, 2000.
4. Wit Grzesik, *"Advanced Machining Processes of Metallic Materials: Theory, Modelling and Applications",* Elsevier, 2008.
5. Chattopadhyay, A.B., *"Machining and Machine Tools",* Wiley India, 2011.

16ME602 THEORY OF PLASTICITY AND METAL FORMING 3-0-0-3

Fundamentals: Elastic, anelastic and plastic behavior. Mechanical properties. Stress-strain curves for ductile and brittle alloys. Dislocations and plastic deformation. Slip phenomenon. Introduction to elasticity: Analysis of stress and strain; stress at a point; stress tensor; stress transformations; principal stresses; octahedral stress; equations of equilibrium. Strain tensor; principal strains; strain-displacement relations; compatibility conditions; constitutive equations. Theory of plasticity: Introduction; flow curve; true stress and true strain; yielding criteria for ductile metals; combined stress tests; yield locus; anisotropy in yielding; yield surface and normality; octahedral shear stress and shear strain; invariants of stress and strain; plastic stress-strain relations; two dimensional plastic flow; slip line field theory.

Fundamentals of metal working: Classification of forming processes; mechanics of metal working; flow stress determination; temperature in metal working; strain-rate effects; metallurgical structure; friction and lubrication. Forging: Classification; forging in plane strain; calculation of forging loads; forging defects; residual stresses in forgings.

Rolling of metals: Classification; hot and cold rolling; forces and geometrical relationships; simplified analysis of rolling load; rolling variables; problems and defects in rolled products; torque and power.Extrusion: Classification; deformation; lubrication; defects; analysis of extrusion process.Drawing of rods, wires and tubes: Introduction; analysis of wire and tube drawing; residual stresses.Sheet metal forming: Introduction; forming methods; shearing; blanking; bending; stretch forming; deep drawing; forming limit criteria; defects in formed parts.
Codes and Standards

TEXT BOOKS/REFERENCES:

1. Timoshenko, S. P. and Goodier, J. N., "*Theory of Elasticity*", Third Edition, McGraw Hill, 1970.
2. Chakrabarthy, J., "*Theory of Plasticity*", Third Edition, McGraw Hill, 2006.
3. Dieter, G. E., "*Mechanical Metallurgy*", Third Edition, McGraw Hill, 1988.
4. Waboner, R. H. and Chenot, J. L., "*Metal Forming Analysis*", Cambridge University Press, 2001.
5. Henry S.Valberg., *"Metal Forming",* Cambridge University Press, 2010.

16ME650 MANUFACTURING AUTOMATION 3-0-1-4

Introduction to Automation - Automated manufacturing systems. Sensors and Actuators in Automation - Digital and analog sensors; Fluid power actuators; Control valves; Electrical system elements; Motors drives; Mechanical devices. Control Using PLCs - Relay logic; Combinational and sequential control; Minimization of logic equations; Ladder logic diagrams; Programmable logic controllers (PLCs); PLC components; Programming; I/O addresses; Timer and counters; A/D conversion and sampling; PLC applications. Pneumatic and Hydraulic Systems - Pneumatic fundamentals - control elements, position and pressure sensing - logic circuits - switching circuits - sequential circuits - cascade method. Elements of hydraulic systems such as pumps, valves, filters, reservoirs, accumulators, actuators, intensifiers etc. Selection of hydraulic fluid, practical

case studied on hydraulic circuit design and performance analysis. Servo valves, electro hydraulic valves, proportional valves and their applications - hydro pneumatic circuits.
Material Handling - Mechanization devices and material handling systems; Mechanization of parts handling; Parts feeding; Parts sensing; Automated Guided Vehicle. Industrial Robotics - Robot anatomy - Work volume - Drive systems - Sensors in robotics - Robot reference frames and coordinates and robot kinematics. End effectors: Mechanical and other types of grippers - Tools as end effectors - Robot end effectors interface. Robot kinematics. Typical applications of robots: material transfer, machine loading/unloading; processing operations; assembly and inspection.
Lab Practice - Fluid power circuit simulation, PLC Programming, Robot Programming, Simple projects using Arduino and Rasberry Pi platforms.

TEXT BOOKS/ REFERENCES:

1. Mikell P. Groover, *"Automation, Production Systems and Computer Integrated Manufacturing"*, Third Edition, Pearson Education, 2009.
2. Robert J. Schilling, *"Fundamentals of Robotics, Analysis & Control",* Prentice Hall, 2009.
3. Chang, T. C., Wysk, R. A., and Wang, H. P., *"Computer-Aided Manufacturing",* Prentice Hall, 2008.
4. Antony Espossito, *"Fluid Power with Applications "*, Pearson, Sixth Edition., 2003.
5. Nanua Singh, Tatla Dar Singh., *"Systems Approach to Computer-Integrated Design and Manufacturing",* John Wiley and Sons, 1995.

16ME661 MANUFACTURING ENGINEERING LAB 1 0-0-1-1

Machining and forming: Machining: Forces in turning, drilling, milling and grinding, study of process parameters and its effects, manufacturing process simulation. Press working- load calculations for blanking, bending and forming operations and practise.
CNC Programming and practice.
Metal joining: Welding: –Study and practise of GMAW &GTAW processes for various Metals and alloys like Stainless steel etc.

16ME651 ADVANCED CASTING TECHNOLOGY 3-0-0-3

Principles and applications of vacuum melting processes: Induction, Vacuum Arc, Skull, Plasma Arc and Electron Beam Melting. Melting of Nickel, Titanium, Iron and Cobalt based alloys. Melt processing: Principles of degassing, grain refining and modification.
Advanced casting processes: Low Pressure Gravity Die casting, Counter Gravity Sand Casting, Investment Casting, and Squeeze Casting. Thixo-moulding and Resin-bonded moulding processes. Directional Solidification of single crystal and columnar-grained castings and its application to aerospace castings. Metal infiltration technology and Casting of Metal Matrix Composites. Case studies.
Principles of fluid flow and heat transfer in casting solidification. Gating and riser design by simulation methods using software packages. Heat transfer models for various casting processes: sand, gravity die, low pressure die, squeeze, investment, direct chill and

continuous casting. Simulation of these processes using software packages. Prediction of casting defects-porosity, segregation, shrinkage and hot tearing.

TEXT BOOKS/ REFERENCES:

1. Beeley, P., *"Foundry Technology"*, Second Edition, Butterworth/Heinemann, 2001.
2. Heine, R. and Rosenthal P., *"Principles of Metal Casting"*, Tata McGraw Hill, New Delhi 1980.
3. Kou, S., *"Transport Phenomena in Materials Processing",* John Wiley and Sons, 1996
4. Metals Handbook, Vol.15, "*Casting"*, ASM International, Metals Park, Ohio, 1988.
5. Yu, K.O., *"Modelling for Casting and Solidification Processing"*, Marcel Dekker, 2002.

16ME652 LEAN MANUFACTURING 3-0-0-3

Lean Manufacturing - Introduction - History of Lean – Toyota Production System-comparison to other methods - The 7 Wastes, their causes and the effects – An overview of Lean Principles / concepts / tools - Stockless Production. Tools of Lean Manufacturing- Continuous Flow - Continuous Flow Manufacturing and Standard Work Flow - 5S and Pull Systems (Kanban and ConWIP systems) - Error Proofing and Set-up Reduction – Total Productive Maintenance (TPM) - Kaizen Event examples. Value Stream Mapping – Current state and Future State- Ford Production Systems. Building a Current State Map (principles, concepts, loops, and methodology) - Application to the factory Simulation scenario. Key issues in building the Future State Map - Process tips in building the map and analysis of the customer loop, supplier loop, manufacturing loop and information loop - Example of completed Future State Maps Factory simulation – Implementation of lean practices - Best Practices in Lean Manufacturing. Six Sigma Fundamentals -Selecting Projects – Six Sigma Statistics - Measurement System Analysis - Process Capability - DMAIC – Define, Measure, Analyze, Improve, Control. Lean Six Sigma – Four Keys to Lean Six Sigma - Key #1: Delight Your Customers with Speed and Quality Key #2: Improve Your Processes Key #3: Work Together for Maximum Gain Key #4: Base Decisions on Data and Facts - Five Laws of Lean Six Sigma - Case Studies.

TEXT BOOKS/ REFERENCES:

1. James P. Womack, Daniel T. Jones and Daniel Roos, *"The Machine that Changed the World: the Story of Lean Production",* Simon & Schuster, 1996.
2. Jeffrey K. Liker, "*Becoming Lean",* Industrial Engineering and Management Press, 1997.
3. James P. Womack and Daniel T. Jones, "*Lean Thinking",* Free Press-Business and Economics, 2003.
4. Rother M. and Shook J., *"Learning to See*", The Lean Enterprise Institute, Brookline, 2003.
5. George, Michael. L. "Lean Six Sigma: Combining Six Sigma Quality with Lean Speed", Tata McGraw Hill Education, New Delhi, 2002.
6. Larson Alan,"Demystifying Six Sigma : A Company-wide Approach to Continuous Improvement", Jaico, Mumbai, 2007.

16ME653 ADVANCES IN MANUFACTURING TECHNOLOGY AND METROLOGY 3-0-0-3

Precision engineering – concepts and significance – micro fabrication – types - top down– bottom up approaches –Micro Electro-Mechanical Systems (MEMS) - LIGA process –lithography steps – X ray lithography – masks – mask materials. Micromachining –theory of micromachining – types – concepts – tools used in micromachining – microEDM – micro wire cut EDM – micro ECM – micro EDG - abrasive jet micromachining -water jet micromachining. Laser based micromachining – types of Lasers – diode, Excimer and Ti: Sapphire lasers – nanosecond pulse micro fabrications – shielding gas.Nano-engineering –concepts – significanceand applications – Nano surface generation – diamond turning – ELID grinding – electronbeam Nano fabrication.

Micro Metrology- Principle of Scanning, Transmission Electron and Atomic Force microscopes. Case studies of metallographic examination using SEM, TEM and AFM. Material characterization using EDS and XRD.Laser principles and its use in Metrology - Laser Interferometer and its applications. Calibration of linear accuracy in CNC machines using Interferometer setup. Important features of co-ordinate measuring machine.CMM probing system and its usage for specific applications.CMM software, programs and mode of operation – subroutines for shapes and geometric form and positional relationships. Simple case studies of CMM programming.Machine vision systems – Image acquisition and digitization – Illumination techniques – Image processing and analysis – Pattern matching – Interpretation – Text verification and reading – Optical character recognition (OCR) – Edge detection techniques - Case studies of machine vision applications – Faulty component identification and counting.

TEXT BOOKS/ REFERENCES:

1. Marc J. Madou, *"Fundamentals of Microfabrication"*, Second Edition, CRC Press,2002.
2. Jain, V. K., *"Introduction to Micromachining",* Narosa Publishing House, 2010.
3. Tai – Ran Hsu, *"MEMS and Microsystems: Design and Manufacturing",* TataMcGraw Hill, 2002.
4. Bechwith-Marangoni-Lienhard, *"Mechanical Measurements",* Pearson Education Asia, Sixth Edition, Reprint 2009.
5. Marshall A. D. and Martin R. R., *"Computer Vision, Models and Inspection",* World Scientific, 1992.
6. NelloZuech, *"Understanding and Applying Machine Vision"*, Second Edition, Marcel Dekker, 2000.

16ME662 MANUFACTURING ENGINEERING LAB II 0-0-1-1

System Simulation:

Modeling and analysis of manufacturing and materials handling systems and service systems through simulation - ARENA.

Analysis of simulation input data and fit the data into a suitable distribution using ARENA Input Analyzer – Simulation output analysis - Performance Modelling of

Assembly shops, FMS, Flow shop, Jobshops, and Kanban Controlled Manufacturing Systems – Modeling of material handling systems - Simulation optimization.

16ME663 MANUFACTURING ENGINEERING LAB III 0-0-1-1

CAD: Exercises covering sketching, modelling, assembly, interference checking, drafting, generation of BOM. Exercises involving customization of CAD software using VB programming.

FEA: Exercises covering structural analysis, dynamic analysis using and thermo mechanical coupled analysis FEA packages– Finite element modelling of metal forming and metal cutting operation. Mold design and analysis using mold flow software.

16ME664 RESEARCH METHODOLOGY 0-0-1-1

An Introduction to Research - What Constitutes Good Research - Modalities of Research in Engineering : Experimental, Theoretical and Computational - Basic understanding of the various modalities and their challenges, Formulating a Research Problem, Defining the research problem

Literature Review and its importance, Making a Good Literature Survey, Sources of Literature - Journal Databases, Conference Proceedings and other important sources - How to do a good literature review, How should literature review be written in thesis and journals.

Journals, Citation Index, Thesis and Journal Writing, Citation Methods and Styles, Technical Writing for Research - An Introduction to Latex and using it for technical writing – JapRef, math editor.

Techniques for Data Analysis - An introduction to basic statistical tools, basic data analysis and mining tools, hypothesis testing, fundamentals of linear algebra and optimization theory.

Introduction to methodologies – Analytical Hierarchy Process, Analytical Network Process, Interpretive Structural Modeling, System Dynamics. An introduction to EXCEL for Data Analysis. An introduction to MATLAB and Simulink.

16ME654 PRODUCTION AND OPERATIONS MANGEMENT 3-0-0-3

Role of Production.- Production Control Information Flow - CAD/CAM and Production Control. Forecasting Demand forecasting – techniques – Moving average – Exponential smoothing . Techniques for causal analysis such as simple linear regression analysis and multiple regression analysis. Aggregate planning - Aggregate production planning – use of LPP formulation – Master production schedule –techniques – Bill of materials – MPS. Techniques for MRP – lot sizing-capacity planning and control – Scheduling capacity and materials. Lots Sizing Concepts Inventory management – continuous review and periodical review policies – models for determining economic order quantity with holding and shortage costs- backlogging-constrained inventory optimization models. Sequence Scheduling - Scheduling on single and multiple machines – Scheduling with multiple constraints – exact and heuristic techniques Line Balancing-A Key to

Automation. Project Planning and Resource Constrained Scheduling. JIT and Lean systems Just-in-time and lean manufacturing systems.

TEXT BOOKS/ REFERENCES:

1. David D. Bedworth and James E. Bailey, *"Integrated Production, Control Systems: Management, Analysis and Design",* Second Edition, Management Science, 1993.
2. Thomas E. Vollmann, *"Manufacturing Planning and Control for Supply Chain Management"*, Fifth Edition, McGraw Hill, 2005.
3. Evans, J. R., *"Production and Operations Management",* Fifth Edition, West Publishing, 1998.
4. William J. Stevenson, Mehran Hojati, *"Production/Operations/Management",* McGraw-Hill Ryerson, Limited, 2001.
5. Chary,S.N., *""Production and Operations Management",* Fourth Edition, Tata McGraw Hill,2009.

16ED654 OPTIMIZATION TECHNIQUES IN ENGINEERING 2-0-1-3

Introduction to Optimization: Engineering application of Optimization – Statement of an optimization problem - Optimal Problem formulation - Classification of optimization problems. Definition of Global and Local minima. Unconstrained Optimization: Optimality Conditions – Algorithms for univariate optimization – Algorithms for multivariate optimization – Convergence of algorithms - Engineering applications of unconstrained algorithms. Lagrange multiplier Theory & Duality: Lagrange multipliers - Kuhn-Tucker Optimality Conditions and sufficiency for convex problems – Lagrangian duality – Saddle point Conditions. Constrained Optimization: Optimality Conditions – Feasible direction methods – Frank-Wolfe algorithm – Gradient Projection – Active set methods - Penalty function methods – Constrained steepest descent method. Modern methods of Optimization: Genetic Algorithms - Simulated Annealing – Tabu search - Ant Colony optimization – Particle Swarm Optimization – Neural-Network based Optimization – Fuzzy optimization techniques. Introduction to Multi-Objective optimization – Classical methods – Pareto Optimality – Use of evolutionary algorithms for solving Multi-Objective optimization problems. **Lab Practice:** Use of programming languages and Matlab to solve optimization problems.

TEXT BOOKS/ REFERENCES:

1. Kalyanmoy Deb, "*Optimization for Engineering Design Algorithms and Examples",* Prentice Hall, 2000.
2. Rao, S. S., *"Engineering Optimization Theory and Practice",* Fourth Edition, New Age International, 2009.
3. Saravanan. R., *"Manufacturing Optimization Through Intelligent Techniques"*, Taylor & Fransis, CRC Press, 2006.
4. Ravindran, Phillips and Solberg, *"Operations Research Principles and Practice"*, Wiley India, 2007.
5. Hadley, G., *"Non Linear and Dynamic Programming"*, Addison Wesley, 1964.

16ME701 FINITE ELEMENT METHODS 3-0-0-3

Fundamentals of governing equations in Solid Mechanics and Heat Transfer. Strong form, weak form, Variational formulation, weighted residual method - Galerkin formulation, Formulation of the finite element equations - Element types - Basic and higher order elements- Coordinate systems. Finite elements in Solid Mechanics: analysis of trusses, beams and frames, Plane stress, plane strain and axisymmetric elements, Plate and shell elements.- Isoperimetric formulation. Finite elements in Heat Transfer: Formulations and solution procedures in one-dimensional and two-dimensional problems. Structural dynamics: Formulation - Element mass matrices - Evaluation of Eigen values and Eigen vectors - Natural frequencies and mode shapes - Numerical time integration.
Computer implementation of the Finite element method: pre-processing, element calculation, equation assembly, Solving, Post processing – primary and secondary variables. Introduction to computational packages.

TEXT BOOKS/REFERENCES:

1. Rao, S. S., "*The Finite Element Method in Engineering*", Fourth Edition, Elsevier, 2007.
2. Jacob Fish and Ted Belytschko, "*A First Course in Finite Elements*", Wiley Inter Science, 2007.
3. David V. Hutton, "*Fundamentals of Finite Element Analysis*", McGraw Hill, 2005.
4. Daryl L. Logan, "*A First Course in the Finite Element Method*", Fourth Edition, Cengage Learning, 2007
5. Zienkiewicz, O.C., Taylor, R.L., and Zhu, J.Z., "*The Finite Element Methods, Vol.1- The Basic Formulation and Linear Problems"*, Butterworth Heineman, Sixth Edition, 2005.

16ME702 SURFACE ENGINEERING 3-0-0-3

Characteristics and Tribology of surfaces: Classification of surfaces and properties. Protection and modification. Friction of solids and wear. Surface Treatment and Coating: Heat and diffusion techniques. Physical/chemical vapor deposition; plasma spray coating; plasma assisted ion implantation; surface modification by directed energy beams like ion, electron and laser beams; energy transfer, beam configuration and modes. Solid lubricants coating and surface corrosion resistance. Micro Arc Oxidation/Plasma Electrolytic Oxidation process.
Process Modelling: Diffusion phenomenon and equation. Effects of phase transformation. Simulation of surface modification processes. Solutions for practical problems. Characterization: Novelty of composition and microstructure - post irradiation characterization and testing/evaluation of surface-properties - structure-property correlation. Failure mechanisms.

TEXT BOOKS/ REFERENCES:

1. Griffiths, B*., "Manufacturing Surface Technology",* Taylor and Francis, 2001.
2. Davis, J. R., *"Surface Engineering for Corrosion and Wear Resistance"*, Maney, 2001.
3. Halling, J., *"Principles of Tribology",* Macmillan, 1992.

4. Ohring,M., *"The Materials Science of Thin Films",* Academic Press Inc., 2005.
5. Pradeep L. Menezes, "Tribology for Scientists and Engineers", Springer, 2013

16ME703 DESIGN OF EXPERIMENTS 3 0 0 3

Introduction to Research, Review of linear estimation, basic designs and Design Principles, Completely Randomized Designs, Treatment Comparisons, Diagnostics and Remedial Measures, Experiments to Study Variances, Random Effects Models. Factorial Designs: General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects; study of 2n and 3r factorial experiments in randomized blocks; complete and partial confounding, construction of symmetrical confounded factorial experiments, fractional replications for symmetrical factorials, split plot and strip-plot experiments. Complete Block Designs: Balanced incomplete block designs, simple lattice designs, Two-associate partially balanced incomplete block designs: association scheme and intra block analysis, group divisible design. Analysis of Covariance including a Measured Covariate Split-Plot Designs, Repeated Measures Designs, missing plot technique:- General theory and applications, Analysis of Co-variance for CRD and RBD. Application areas: Response surface experiments; first order designs, and orthogonal designs; clinical trials, treatment-control designs; model variation and use of transformation; Tukey's test for additivity.

TEXT BOOKS/ REFERENCES:

1. Douglas C. Montgomery, *"Design and Analysis of Experiments*", Seventh Edition, Wiley, 2010.
2. Jiju Antony, *"Design of Experiments for Engineers and Scientists",* Elsevier, 2003.
3. Larry B. Barrentine**,** ***"****An Introduction to Design of Experiments: A Simplified Approach"*, ASQ Quality Press, 1999.
4. Paul G Mathews, *"Design of Experiments with MINITAB*", ASQ Quality Press, 2003.
5. Mark J. Anderson, Patrick J. Whitcomb, *" DOE Simplified: Practical Tools for Effective Experimentation",*Second Edition, Productivity Press,2007.

16ME704 ADVANCED WELDING TECHNOLOGY 3-0-0-3

Description and application of advanced welding processes: GTA, GMA, friction stir, electron and laser beam, plasma arc and electro-slag welding.

Solidification behaviour in fusion welding: weld pool shape and columnar grain structures, solidification microstructures, solute redistribution and peritectic solidification. Grain growth in welds. Solid-state transformations in welds. Weldability of Al, Fe, Cu, Ti based alloys.

Welding heat sources: types and characteristics. Modelling of heat distribution: stationary and moving heat sources. Modelling of heat flow during welding and prediction of thermal history: steady state, transient and pseudo-steady state heat conduction. Prediction of cooling rate and its effects on microstructure and mechanical properties.

Welding defects. Residual stress and distortion in welding. Numerical analysis of residual stresses in welding processes. Control of distortion.

Lab: Numerical Analysis using Multi Physics Software.

TEXT BOOKS/ REFERENCES:

1. Grong, O, *"Metallurgical Modelling of Welding*", Second Edition, The Institute of Materials, 1997.
2. Kou, S., *"Welding Metallurgy",* Second Edition, John Wiley Publications, New York, 2003.
3. Metals Handbook, Vol. 6, "*Welding, Brazing and Soldering",* ASM International, Metals Park, Ohio, 1988.

16ME705 EMBEDDED SYSTEMS 3-0-0-3

Embedded system concepts, sensors, actuators and real-time systems, embedded hardware and software, application of microcontrollers in manufacturing process control.
Real-Time process monitoring and control in manufacturing processes: machining, metal forming and welding, Roles of Sensors in Manufacturing and Application Range, Sensors for machine tools and robots, workpieces and process monitoring, Classification and types, mechatronics systems in Computer Aided and Integrated Manufacturing Systems,
Industrial Networks in manufacturing: CAN and Ethernet based networks, Networking of Sensors and control systems in manufacturing, Computer communications: layers and protocols, Flexible manufacturing systems: robot control through vision sensors, Real-time embedded control in distributed networks, Applications of Industrial Networks for Control, Diagnostics and Safety

TEXT BOOKS/ REFERENCES:

1. Richard Zurawski, *"Embedded Systems Handbook: Networked Embedded Systems",* Second Edition, CRC Press, 2009.
2. Dogan Ibrahim, *"Microcontroller Based Applied Digital Control",* John Wiley and Sons, 2006.
3. Sabrie Soloman, *"Sensors and Control Systems in Manufacturing",* Second Edition, McGraw Hill, 2010.
4. Cornelius T. Leondes, *"Computer Aided and Integrated Manufacturing Systems-Volume 5: Manufacturing Processes*", World Scientific Publishing, 2003.
5. Jan Wikander and Bertil Svensson, *"Real-Time Systems in Mechatronic Applications"*, Kluwer Academic Publishers, 1998.

16ME706 LOGISTICS AND SUPPLYCHAIN MANAGEMENT 3-0-0-3

Introduction: Introduction to SCM-the complexity and key issues in SCM – Location strategy – facility location decisions – single facility and multiple location models.
Logistics: Logistics Network Configuration – data collection-model and data validation-solution techniques-network configuration DSS – Transport strategy – Service choices: single service and inter modal services – vehicle routing and scheduling models – travelling salesman problems – exact and heuristic methods. Inventory strategy:

Inventory Management and risk pooling-managing inventory in the SC. The value of information - bullwhip effect - lead time reduction. Supply chain integration: Supply chain integration-distributed strategies-push versus pull systems. Distribution Requirements planning – DRP and demand forecasting, DRP and master production scheduling. DRP techniques – time-phased order point – managing variations in DRP – safety stock determination-Strategic alliances-third party logistics-distribution integration. Issues in SCM: Procurement and outsourcing strategies – framework of e-procurement. International issues in SCM-regional differences in logistics. Coordinated product and supply chain design-customer value and SCM.

TEXT BOOKS/ REFERENCES:

1. David Simchi-Levi and Phlip Kamainsky, *"Designing and Managing the Supply Chain: Concepts, Strategies, and Cases*", McGraw Hill, 2002.
2. Martin Christopher, *"Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service",* Prentice Hall, 1999.
3. Ronald Ballou, *"Business Logistics / Supply Chain Management*", Pearson Education, 2003.
4. Thomas E. Vollmann, Willan L. Bery, Robert Jacobs, F., and David Clay Bark, *"Manufacturing Planning and Control for Supply Chain Management",* Fifth Edition, McGraw Hill, 2005.

16ME707 COMPOSITE MATERIALS AND PROCESSING 3-0-0-3

Types and forms of reinforcement and their properties. Pre-fabricated forms. Selection of matrices: physical and mechanical properties. Bonding mechanisms. Types of reinforcement distributions: uniform, gradient and surface. Factors in composite design. Structure-property relationships. Models of various materials properties of composites: density, modulus, strength, specific heat, coefficient of thermal expansion, thermal conductivity and diffusivity, electrical conductivity and dielectric constant. Isotropic and anisotropic properties.

Fabrication techniques: infiltration, casting, reaction sintering, electro-deposition, diffusion bonding, thermal and plasma spray forming, laser method, powder forming, additive processes, crystal growth and physical vapour deposition. Testing and inspection methods. Review of case studies.

TEXT BOOKS/ REFERENCES:

1. Clyne, T. W. and Withers, P. J., *"An Introduction to Metal Matrix Composites"*, Cambridge University Press, 1993.
2. Matthews, F. L. and Rawlings, R. D., *"Composite Materials: Engineering and Science",* Chapman and Hall, London, 1994.
3. Suresh, S., Martensen, A., and Needleman, A., *"Fundamentals of Metal Matrix Composites"*, Butterworth Heinemann, 1993.
4. Kainer, K.U., "Metal Matrix Composites: Custom-made Materials for Automotive and Aerospace Engineering", Wiley-VCH, 2006.
5. Chawla, N. and Chawla. K. K., "Metal Matrix Composites", Springer, 2006.

16ME708 PRODUCT LIFECYCLE MANAGEMENT 3-0-0-3

Introduction to Product life cycle - PLM- PDM concepts -present market constraints - need for collaboration – Object oriented programming concepts - internet and developments in server - client computing. Components of a typical PLM / PDM setup - hardware and software - document management - creation and viewing of parts and documents- version control -case studies. Configuration management: Base lines - product structure - configuration management – Effectivity - case studies.
Creation of projects and roles - life cycle of a product- life cycle management - automating information flow-workflows - creation of work flow templates -life cycle - work flow integration - case studies. Change management: Change issue- change request- change investigation- change proposal - change activity - case studies. Generic products and variants: Data Management Systems for FEA data - Product configuration - comparison between sales configuration and product configuration -generic product modeling in configuration model - use of order generator for variant creation-registering of variants in product register-case studies. Implementation issues and best practices.

TEXT BOOKS/ REFERENCES:

1. Kevin Otto and Kristin Wood, *"Product Design"*, Pearson, 2001.
2. Daniel Amor, *"The E-Business Revolution"*, Prentice Hall, 2000.
3. David Bed Worth, Mark Henderson, and Phillip Wolfe, *"Computer Integrated Design and Manufacturing"*, McGraw Hill, 1991.
4. Terry Quatrain., *"Visual Modeling with Rational Rose and UML"*, Addison Wesley, 1998.
5. Antti Saaksvuori and Anselmi Immonen, *"Product Life Cycle Management"*, Second Edition, Springer, 2005.

16ME709 TOOL ENGINEERING AND DESIGN 3-0-0-3

Cutting tools: Design of single point tool-strength and rigidity consideration, Design of twist drill, milling cutters, reamers and broaches. Jigs & Fixtures: Tolerance analysis and procedure of designing. The economic calculations, location of the work piece, degree of freedom, references surfaces, resting components, fixture elements for surface concentric and radial locations – Clamping of the workpiece, review of cutting forces, principles and methods of clamping. Quick clamping devices, standards. Guiding elements for tools, jig bushes, standards – indexing methods – standards in design of Jigs/Fixtures/Accessories for Drilling, Milling, Turning, Broaching, and Grinding. Press tool design: Introduction terminology shearing dies- types of dies – analysis process shearing clearance –size and tolerances of die opening and punch – force, power, energy in shearing – loading center, shearing with inclined edges – strip layouts, economical stock. Design of Compound and progressive dies. Design of bending, drawing and forming dies- blank development, strain factor, calculation of force, construction of drawing and drawing dies.

TEXT BOOKS/ REFERENCES:

1. Cyril Donaldson and Donaldson Mn, *"Tool Design"*, Third Edition, Tata McGraw-Hill Education, 2001.
2. Edward G. Hoffman, *"Jig and Fixture Design"*, Cengage Learning, 2004.
3. Paul D. Q. Campbell, *"Basic Fixture Design"*, Industrial Press Inc., 1994.

16ME710 ADVANCES IN PROCESS TECHNOLOGY 3-0-0-3

Selected topics on recent advances in various areas of manufacturing process technologies-casting, welding, forming, electroforming, melt spinning, moulding, surface modification by physical and chemical vapour deposition techniques, thermal spray coating processes, vacuum arc deposition, sputter deposition, surface hardening, e-beam, laser and plasma processing, diffusion bonding, hot isostatic pressing, composite processing and rapid prototyping. New materials including carbon, silicon carbide and alumina fibres and their manufacturing methods. Case studies.

TEXT BOOKS/ REFERENCES:

1. Griffths B., *"Manufacturing Surface Technology",* Taylor and Francis, 2001.
2. Schwartz M., *"New Materials, Processes, and Methods Technology"*, Taylor and Francis, 2006.
3. Yu K.O., *"Modeling for Casting and Solidification Processing"*, Marcel Dekker, 2002.
4. Grong O, *"Metallurgical Modeling of Welding"*, Second Edition, The Institute of Materials, 1997.
5. Kainer K.U*., "Metal Matrix Composites: Custom-made Materials for Automotive and Aerospace Engineering",* Wiley-VCH, 2006.

16ME711 RELIABILITY ENGINEERING 3-0-0-3

Concept and Definition of reliability (reliability mathematics)-Failure distributions, hazard models – exponential, Rayleigh, Weibull, Normal and Lognormal distributions - MTTF, MTBF. Reliability of systems – series and parallel configurations - Reliability improvement, redundancy, k-out-of-n system -Reliability of complex configurations-Reliability of three-state devices – Markov analysis-Physical reliability models – random stress and random strength-Design for reliability-Reliability allocation, derating-Maintainability-Design for maintainability-Availability-Maintenance and space provisioning. Failure data analysis-Reliability Testing-Identifying failure distributions– parameter estimation.

TEXT BOOKS/ REFERENCES:

1. Charles Ebeling, *"An introduction to Reliability and Maintainability Engineering",* Tata McGraw Hill, 2000.
2. Lewis E. E., *"Introduction to Reliability Engineering",* Second Edition, John Wiley and Sons, 1995.
3. Rao S. S., *"Reliability Based Design",* McGraw Hill, 1992.
4. Barlow R. E., Proselan F., and Hunter L. C., *"Mathematical Theory of Reliability",* John Wiley, 1965.
5. Srinath L.S., *"Mechanical Reliability",* East-West Press, 2002.

16ME712 COMPUTER AIDED PRODUCT DEVELOPMENT 3-0-0-3

Introduction to New Product design – Creativity and Innovation - concept design – parametric sketching – constraints- Feature based modelling - synchronous technology – contemporary software – Kernel and graphics engine – Hardware requirements - data exchange formats. Computers in Design — Assembly modelling – creation of BOM – issues in large assemblies - associative features – Sheet metal components, nesting and development – plastic parts with draft and shrinkage allowance – Reverse engineering of components – tolerance analysis – check for interferences and mass property calculations Computers applications in tool design – mould design – jigs and fixtures design – mechanism design and analysis – Rapid tooling – Computer aided inspection. Computers in Design Productivity – customisation using various software like visual basic, pro/program, script, LISP etc. to write applications like design of shafts, gears etc. Managing product design data – version control – library creation – catalogue making – standardization for design – collaborative design among peer groups – design optimization for geometry - Design check, approval and validation. – introduction to design patenting rules.

TEXT BOOKS/ REFERENCES:

1. William M. Neumann and Robert Sproul, *"Principles of Computer Graphics",* McGraw Hill, 1989.
2. Ibrahim Zeid, *"CAD/CAM – Theory and Practice"*, McGraw Hill, 1998.
3. Rao P. N.*, "CAD/CAM: Principles and Applications",* Second Edition, Tata McGraw Hill, 2004.
4. Schlechtendahl E. G., *"CAD – Data Transfer for Solid Models*", Springer Verlag, 1989.
5. Donald Hearn and Pauline Baker M., *"Computer Graphics"*, Prentice Hall, 1992.

16ME713 QUALITY ENGINEERING 3-0-0-3

Basic concepts in Quality Engineering: definitions, approaches and relevance to organizational excellence. Quality and Competitiveness. Product quality control: Acceptance sampling methods- single, multiple and sequential sampling plans; Recent developments in inspection methods. Statistical Process Control: Process evaluation and control by control charts: x-bar and R-bar charts, Moving Average and Moving Range Charts, Charts for Individuals, Median and Range Charts. Control Charts for Attributes - Non-conforming, Non-conformities (defects). Process capability studies: Various indices and approaches; use of Nomographs; Discussions on capabilities of Process. Quality costs-Quality measurement. Total Quality Management perspective, methodologies and procedures; Roadmap to TQM, ISO 9000, KAIZEN, Quality Circles, Models for organizational excellence. Quality Function Deployment, Quality Cost Systems and Quality Policy Deployment. Implementation of TQM and the management of change.
Process evaluation and control by designs of experiment: Various basic designs; Special methods such as EVOP and ROBUST design (Taguchi Methods). Six Sigma Management: Concepts, Steps and Tools; Benchmarking and Balanced Score Cards. TPM, FMECA, Fault Tree Analysis, Quality and reliability perspectives of JIT. Training for Quality. Application of Software tools and Case Studies.

TEXT BOOK/ REFERENCES:

1. Douglas C. Montgomery, *"Design and Analysis of Experiments*", Seventh Edition, Wiley, 2010.
2. Juran J.M., *"Quality Control by Design",* The Free Press, 1992.
3. Mitra A., *"Fundamentals of Quality Control and Improvement",* PHI, Second Edition, 2005.
4. Evans J.R. and LindsayW.M., *"The Management and Control of Quality",* Thomson, 2005.
5. Wadsworth H.M., Stephens K.S. and Godfrey A.B., "*Modern Methods for Quality Control and Improvement"*, John Wiley and Sons, 2004.

16ME714 ADDITIVE MANUFACTURING 3-0-0-3

Classification of rapid manufacturing processes- additive/subtractive/formative. Process chain for additive and other rapid manufacturing processes. Data formats and conversion. Slicing algorithms, part deposition orientation.

Material science for additive manufacturing- polymer and photopolymerization, polymer and selective layer sintering, laser chemical vapor deposition, direct metal deposition, design of tailored structure for end application. Mathematical models for additive manufacturing- temperature, fluid flow and composition.

Additive Manufacturing Systems: Stereolithography, 3-D Printing, Selective Laser Sintering, direct metal deposition and Light Engineered Net shaping- process parameters, powder / polymer preparation, post fabrication.

Process selection, applications and case studies.

TEXT BOOKS/ REFERENCES:

1. Ian Gibson, *"Additive Manufacturing Technologies:-Rapid Prototyping to Direct Digital Manufacturing*", Springer, 2009.
2. Chee Kai Chua, Ka Fai Liang, "*3D Printing and Ddditive Manufacturing*", World Scientific, 2014.
3. Christopher Barnatt, "*3D Printing*", Explaining The Future.com, 2014.
4. C. K. Chua, K. F. Leong, "*"Rapid Prototyping- Principles and Applications*", World Scientific Publishing", Third Edition, 2010.
5. Paul F Jacobs, *"Stereolithography and other RP&M Technologies: from Rapid Prototyping to Rapid Tooling",* Society of Manufacturing Engineers and the Rapid Prototyping Association, New York, 1996.