M.TECH –MANUFACTURING ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Manufacturing Sector is the engine of growth for our country and it provides a stable economy. According to the technology road map 2035, the manufacturing sector in India needs to grow through adoption of technology platforms which include nano engineering, additive manufacturing, adaptive automation, precision manufacturing and sustainable manufacturing. The Industry needs the skill and creativity to manufacture complex, high specialization products. This program provides an in depth understanding of wide range of domains from general welding, forming, casting and cutting to highly specialized additive manufacturing concepts and is an important link for industrial competitiveness.

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
18MA605	FC	Random Processes and Partial Differential Equations	3	0	2	4
18ME601	FC	Advances in Materials Science and Characterization	3	0	0	3
18ME602	FC	Analysis of Machining Processes	2	0	2	3
18ME603	FC	Theory of Plasticity and Metal Forming	3	0	0	3
18ME650	SC	Manufacturing Automation	3	0	2	4
18RM600	SC	Research Methodology	2	0	0	2
18ME661	SC	Manufacturing Engineering Lab I	0	0	2	1
18HU601	HU	Amrita Values Program*				P/F
18HU602	HU	Career Competency I*				P/F
					Credits	20

*Non credit course

Second Semester

Course Code	Type	Course	L	T	P	Cr
18ME651	SC	Advanced Casting and Welding Technology	3	0	1	4
18ME652	SC	Lean Manufacturing	3	0	0	3
18ME653	SC	Advances in Manufacturing Technology	3	0	0	3
	E	Elective I	3	0	0	3
	E	Elective II	3	0	0	3
18ME662	SC	Manufacturing Engineering Lab II	0	0	2	1

18ME663	SC	Manufacturing Engineering Lab III	0 0 2	1
18HU603		Career Competency II	0 0 2	1
			Credits	19

Third Semester

Course Code	Type	Course	L T P	Cr
18ME654	SC	Additive Manufacturing	2 0 2	3
	E	Elective III	3 0 0	3
18ME798	P	Dissertation		8
			Credits	14

Fourth Semester

Course Code	Type	Course	L T P	Cr
18ME799	P	Dissertation		12
			Credits	12

Total credits: 65

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
18MA605	Random Processes and Partial Differential Equations	3 0 2	4
18ME601	Advances in Materials Science and Characterization	3 0 0	3
18ME602	Analysis of Machining Processes	2 0 2	3
18ME603	Theory of Plasticity and Metal Forming	3 0 0	3

Subject Core

Course Code	Course	L T P	Cr
18ME650	Manufacturing Automation	3 0 2	4
18ME651	Advanced Casting and Welding Technology	3 0 2	4
18ME652	Lean Manufacturing	3 0 0	3
18ME653	Advances in Manufacturing Technology	3 0 0	3
18ME654	Additive Manufacturing	3 0 0	3
18ME661	Manufacturing Engineering Lab I	0 0 2	1
18ME662	Manufacturing Engineering Lab II	0 0 2	1
18ME663	Manufacturing Engineering Lab III	0 0 2	1
18RM600	Research Methodology	2 0 0	2

Electives

Course Code	Course	L T P	Cr
18MA610	Optimization Techniques in Engineering	2 0 2	3
18ME701	Finite Element Methods	3 0 0	3
18ME702	Surface Engineering	3 0 0	3
18ME703	Design of Experiments	3 0 0	3
18ME704	Production and Operations Management	3 0 0	3

18ME705	Logistics and Supply Chain Management	3 0 0	3
18ME706	Composite Materials and Processing	3 0 0	3
18ME707	Product Lifecycle Management	3 0 0	3
18ME708	Tool Engineering and Design	3 0 0	3
18ME709	Reliability Engineering	3 0 0	3
18ME710	Financial Management	3 0 0	3
18ME711	Computer Aided Product Development	2 0 2	3
18ME712	Quality Engineering	3 0 0	3
18ME713	Advanced Materials for Aerospace and Nuclear Applications	3 0 0	3
18ME714	Live in Lab		3

Project Work

Course Code	Course	L T P	Cr
18ME798	Dissertation		8
18ME799	Dissertation		12

18MA605 RANDOM PROCESSES AND PARTIAL DIFFERENTIAL EQUATIONS 3-0-2-4

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. Numerical simulations using Finite Difference and Finite Element Methods.

Matlab, SageMath: 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"*, Sixth Edition, John Wiley and Sons Inc. 2013.
4. Lawrence C. Evans, "*Partial Differential Equations"*, American Mathematical Society, 2010.
5. David Joyner, Marshall Hampton, "*Introduction to Differential Equations Using Sage"*, The Johns Hopkins University Press, 2012.

18ME601 ADVANCES IN MATERIALS SCIENCE AND CHARACTERIZATION 3-0-0-3

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. Welding metallurgy. 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.
Materials characterization techniques – EDS, XRD, SEM, TEM, AFM and NDT – radiography and ultrasonic testing, Liquid Penetrant test, Magnetic particle and Eddy current testing. Codes, Standards and Case Studies.

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.
5. Sam Zhang, Lin Li, Ashok Kumar., *"Material Characterization Techniques",* CRC Press, 2008.

18ME602 ANALYSIS OF MACHINING PROCESSES 2-0-2-3

Mechanics of machining: Systems of tool geometry - Mechanism of chip formation in ductile and brittle materials - Geometry and characteristics of chip forms - Built up edge formation - types of chip and their condition - Orthogonal and oblique cutting - Chip flow deviation - Chip breakers in machining.
Machining forces: Cutting force components in turning, milling and drilling - Construction of Merchant Circle Diagram - Cutting power consumption and specific energy requirement - Analytical models for estimation of cutting forces in orthogonal and oblique cutting – Measurement of cutting forces.
Cutting temperature: Analytical estimation of cutting temperature - Experimental methods - Effect of machining parameters on cutting temperature – Control of cutting temperature and cutting fluid application - Concept of machinability – Failure of cutting tool and tool life - Cutting tool materials - Force and thermal modelling of metal cutting processes using finite element method.
Machining dynamics: Machine tool vibration -Vibration analysis methods- Chatter prediction - Vibration control - Frequency response functions and stability lobe plots – Vibration based condition monitoring of machine tools – Machining dynamics in High speed machining, Thin wall machining and High performance machining - Machining economics and optimization.
Lab: Chip Morphological studies, Cutting force measurement in turning, milling and drilling using dynamometers, Vibration / AE based machine condition monitoring, Experiments related to stability lobes, Process modelling of machining process using Finite Element Packages.
Use of Codes, Standards in machining.

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.
6. Tony L Schmitz and K.Scott Smith, *"Machining* Dynamics", Springer US, 2009.

18ME603 THEORY OF PLASTICITY AND METAL FORMING 3-0-0-3

Metallurgical aspects of metal forming-slip, twinning mechanics of plastic deformation-effects of temperature, strain rate, microstructure and friction in metal forming - yield criteria and their significance-classification of metal forming processes-advantages and limitations-stress strain relations in elastic and plastic deformation-concept of flow stresses-deformation mechanisms-hot and cold working processes and its effect on mechanical Properties.
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: incomplete die filling, die misalignment, laps, incomplete forging penetration, microstructural differences, hot shortness, pitted surface, surface cracking, micro cracking due to residual stresses
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: centreline cracking, warping, edge wrinkling, edge cracking, centre splitting, centreline wrinkling- 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, 3rd edition, 2017.
2. Chakrabarthy, J., "*Theory of Plasticity*", Third Edition, McGraw Hill, 2006.
3. Dieter, G. E., "*Mechanical Metallurgy*", Third Edition, McGraw Hill, 2017.
4. Waboner, R. H. and Chenot, J. L., "*Metal Forming Analysis*", Cambridge University Press, 2005.
5. Henry S.Valberg., *"Applied Metal Forming"*, Cambridge University Press, 2010.

18ME650 MANUFACTURING AUTOMATION 3-0-2-4

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. 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.
Data Monitoring using Arduino/Raspberry Pi: Basic structure - Input / Output processing - Programming -Mnemonics Timers, Internal relays and counters - Analog-to-Digital(A/D) and Digital-to-Analog (D/A) Conversion - Analog input / output, Programming and interfacing with Sensors in manufacturing applications using Python.
Lab Practice - Fluid power circuit simulation, PLC Programming, Robot Programming, Internet of Things Automation using Arduino/ Raspberry Pi.

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 & Sons, 1995.
6. *Gaston C. Hillar, Internet of Things with Python, Packt Publishing Limited, 2016*

18ME661 MANUFACTURING ENGINEERING LAB 1 0-0-2-1

Machining and forming: Machining: Forces in turning, drilling, milling and grinding, study of process parameters and its effects. 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.
Metallographic Studies: similar/dissimilar weldments.

18ME651 ADVANCED CASTING AND WELDING TECHNOLOGY 3-0-1-4

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

Description and application of advanced welding processes: Electron beam welding of advanced materials, diffusion brazing and diffusion bonding of aerospace alloys, ceramic to metal seals, vacuum brazing, controlled atmosphere brazing , laser brazing, friction welding and linear FW friction stir welding, ultrasonic and magnetostrictive welding. 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. 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 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. 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.
6. Grong, O, “Metallurgical Modelling of Welding”, Second Edition, The Institute of Materials, 1997.
7. Kou, S., “Welding Metallurgy”, Second Edition, John Wiley Publications, New York, 2003.
8. Metals Handbook, Vol. 6, “Welding, Brazing and Soldering", ASM International, Metals Park, Ohio, 1988.

18ME652 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.
Ergonomics-as enabler of lean manufacturing, Ergonomic consideration at work, Principles related to: the use of human body, the arrangement of workplace, the design of tools and equipments

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.
7. Barnes, R, "*Motion and Time Study" - Design and Measurement of Work* . NY: John Wiley and Sons, 8th Edition, 1985.

18ME653 ADVANCES IN MANUFACTURING TECHNOLOGY 3-0-0-3

Precision Machining: Ultra Precision turning and grinding: Chemical Mechanical Polishing (CMP) - ELID process – Partial ductile mode grinding-Ultra precision grinding- Binderless wheel – Free form optics. aspherical surface generation Grinding wheel- Design and selection of grinding wheel-High-speed grinding High-speed milling- Diamond turning.

Micro Machining and Nano Fabrication: 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 – micro EDM – 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 machining techniques- Sub micron lithographic technique, conventional film growth technique, Chemical etching, Quantum dot fabrication techniques – MOCVD – Epitaxy techniques.

Surface modification Techniques: 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,

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"*, Tata McGraw Hill, 2002.

4. Jain V.K., "*Advanced Machining Processes*", Allied Publishers, Delhi, 2002.
5. Griffths B., *"Manufacturing Surface Technology"*, Taylor and Francis, 2001.

18ME662 MANUFACTURING ENGINEERING LAB II 0-0-2-1

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.

18ME663 MANUFACTURING ENGINEERING LAB III 0-0-2-1

CAD: Exercises covering sketching, modelling, assembly, interference checking, drafting, generation of BOM. Exercises involving customization of CAD software using VB programming.
Geometric Dimensioning and Tolerance- Standards and Codes.
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.

18ME654 ADDITIVE MANUFACTURING 2-0-2-3

Introduction to layered manufacturing, Importance of Additive Manufacturing Additive Manufacturing in Product Development. Classification of additive manufacturing processes, Common additive manufacturing technologies; Fused Deposition Modeling(FDM), Selective Laser Sintering(SLS), Stereo Lithography(SLA), Selection Laser Melting (SLM), Jetting, 3D Printing, Laser Engineering Net Shaping (LENS), Laminated Object Manufacturing (LOM), Electron Beam Melting (EBM). Capabilities, materials, costs, advantages and limitations of different systems.
Material science for additive manufacturing-Mechanisms of material consolidation-FDM, SLS, SLM, 3D printing and jetting technologies. Polymers coalescence and sintering, photo polymerization, solidification rates,Meso and macro structures, Process evaluation: process-structure relationships, structure property relationships,
Applications: Prototyping, Industrial tooling, Aerospace, Automobive, Medical etc.,
Quality control and reliability: Defects in FDM, SLS and SLM, Critical process parameters: geometry, temperature, composition, phase transformation, Numerical and experimental evaluation: roles of process parameter combination, process optimization.
CAD Modelling for 3D printing: , 3D Scanning and digitization, data handling &reduction Methods, AM Software: data formats and standardization, Slicing algorithms:-uniform flat layer

slicing, adaptive slicing, Process-path generation: Process-path algorithms, rasterisation, part Orientation and support generation.

Lab: CAD Modeling: Introduction to CAD environment, Sketching, Modeling and Editing features, Different file formats, Export/Import geometries, Part orientation, Layer slicing, Process path selection, Printing, Numerical and experimental evaluation.

TEXT BOOKS/ REFERENCES:

1. Gibson, I., Rosen, D.W. and Stucker, B., "Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing", Springer, 2010.
2. Chua, C.K., Leong K.F. and Lim C.S., "Rapid prototyping: Principles and applications", second edition, World Scientific Publishers, 2010.
3. Liou, L.W. and Liou, F.W., "Rapid Prototyping and Engineering applications : A tool box for prototype development", CRC Press, 2011.
4. Kamrani, A.K. and Nasr, E.A., "Rapid Prototyping: Theory and practice", Springer, 2006.
5. Hilton, P.D. and Jacobs, P.F., Rapid Tooling: Technologies and Industrial Applications, CRC press, 2005.

18RM600 RESEARCH METHODOLOGY 2-0-0 2

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, "Research Methodology – Methods and Techniques", 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rd Edition, Elsevier Inc.
4. Michael P. Marder," Research Methods for Science", Cambridge University Press, 2011
5. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age". Aspen Law & Business; 6 edition July 2012

18MA610 OPTIMIZATION TECHNIQUES IN ENGINEERING 2-0-2-3

Introduction to Optimization - Engineering applications - Statement of an optimization problem - Classification - Optimal problem formulation: Problems involving design and manufacturing - Optimality criteria - Classical optimization techniques - Kuhn-Tucker (KT) optimality conditions. Non-linear programming: One dimensional minimization methods - Unconstrained optimization techniques - Constrained optimization techniques - Transformation methods - Interior and exterior penalty function method - Convergence and divergence of optimization algorithms - Complexity of algorithms.

Modern Methods in Optimization: Genetic Algorithm - Simulated Annealing - Particle Swarm Optimization - Neural Network based optimization - Optimization of Fuzzy systems - Multi-Objective optimization - Design of experiment based optimization - Data Analytics and optimization using Machine learning approach.

Implementing optimization algorithm using Matlab / Programming: Design optimization - Robust design - Optimization in manufacturing / machining – Multi objective optimization - Structural optimization - Shape optimization - Optimization in production planning and control.

TEXT BOOKS/ REFERENCES:

1. Kalyanmoy Deb, "*Optimization for Engineering Design Algorithms and Examples*", Prentice Hall, Second Edition, 2012.
2. Rao, S. S., "*Engineering Optimization Theory and Practice*", Fourth Edition, New Age International, 2013.
3. J. S. Arora, "*Introduction to Optimum Design, Academic press*", 4th Edition, 2017.
4. Saravanan. R., "*Manufacturing Optimization through Intelligent Techniques*", Taylor & Fransis, CRC Press, 2006.

18ME701 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*", Fifth Edition, Elsevier, 2011.
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*", Fifth Edition, Cengage Learning, 2012.
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.

18ME702 SURFACE ENGINEERING 3-0-0-3

Introduction to surface engineering-Classification of surfaces and properties-Surface degradation, Wear and Corrosion - types of wear-Roles of friction and lubrication-Overview of different forms of corrosion-Surface treatment and coating: Chemical and Electrochemical polishing, Chemical conversion coatings, Phosphating, Chromating, Chemical colouring, Anodizing of aluminium alloys- Thermo chemical processes-Surface pre-treatment-Deposition of copper, zinc, nickel and chromium - principles and practices-Alloy plating, Electro composite plating, Electro less plating of copper, nickel phosphorous, nickel-boron, electro less composite plating, application areas- Physical/Chemical vapour 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-Diffusion phenomenon and equation-Effects of phase transformation-Simulation of surface modification processes-Solutions for practical problems-Novelty of composition and microstructure-Post irradiation characterization and testing/evaluation of surface, Properties, Structure and Property Correlation-Failure mechanisms

ASTM Standards for Mechanical and Tribological Testing

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

18ME703 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.

18ME704 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.

18ME705 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.

18ME706 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. Laminated Composites, Sample level lamination, case studies.
Experimental techniques, compositional analyses (introduction) and qualification of composites. Instrumental characterization and introduction to advanced characterization techniques (XRD, XRF, ITFR, SEM, TEM, TGA etc). Non-Destructive Analyses of Composites.

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 & 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.

18ME707 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.

18ME708 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.

18ME709 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.

Approaches to intelligent control- AI approach- Concept of artificial neural network and its model, fuzzy logic and its model- Case study

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 & Sons, 1995.
3. Rao S. S., *"Reliability Based Design"*, McGraw Hill, 1992.
4. Srinath L.S., *"Mechanical Reliability"*, East-West Press,2002.
5. Simon Haykins, *"Neural network : A comprehensive foundation"*, Pearson Edition, 2003
6. T. J. Ross, *"Fuzzy logic with fuzzy application"*, McGrawHill, 1997.

18ME710 FINANCIAL MANAGEMENT 3-0-0-3

The finance function – Corporate objectives – Corporate Governance Capital markets, market efficiency and ratio analysis – Business Finance- Capital Markets. An overview of investment appraisal methods – Payback Period – ARR – NPV – IRR methods- Profitability Index and capital rationing- Discounted Payback method Investment appraisal: applications and risk. Project Cash flows- Capital Investment decisions- Risks Sources of long-term finance: equity finance- new issues – rights issues – scrip issues- stock splits- scrip dividends- share repurchases – preference shares . Sources of long-term finance: debt finance, hybrid finance and leasing Dividend policy - The cost of capital and capital structure- –Avg Vs Marginal Cost of Capital. Working capital management. – policies- cash conversion cycles- overtrading - Mergers and takeovers – Strategic and tactical Issues. Risk management- Internal and External risk management – interest and exchange rate risk- International investment decisions- International trade- political risk- foreign investment decisions
Entrepreneurial Finance for New and Emerging Businesses – Identifying and Financing a start up – Measuring and Evaluating financial performance – Venture Capital.

TEXT BOOKS/ REFERENCES:

1. Denzil Watson and Antony Head, *"Corporate Finance Principles and Practice"*, Pearson Education, 2002.
2. Terry S. Manes, *"Introduction to Corporate Finance"*, McGraw Hill, 1998.
3. James C. Vanhorne and John M. Wachowilz, *"Fundamentals of Financial Management"*, Prentice Hall, 1996.
4. Jae K. Shim and Joel G. Siegel, *"Financial Management"*, Barron's Educational Series, 2008.
5. Cornwall, Jeffrey R, Vang, David O and Hartman, Jean M, "Entrepreneurial financial management: An applied approach", Yes Dee Publishing, Chennai, 2009.
6. J. Leach, Ronald Melicher, "Entrepreneurial Finance", 4th Edition, South-western Cengage Learning, USA, 2012.

18ME711 COMPUTER AIDED PRODUCT DEVELOPMENT 2-0-2-3

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. Geometric dimensioning and tolerancing.

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.

18ME712 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 & Sons, 2004.

18ME713 ADVANCED MATERIALS FOR AEROSPACE AND 3-0-0-3

NUCLEAR APPLICATIONS

Detailed study and equipment design for advanced and high tech material processing : Introduction, definition and classification of different types of Engineering Materials for aerospace, space, nuclear and defence applications (such as: Titanium alloys, super alloys, aluminium& light alloys, composites, tungsten –tantalum alloys, Moly and PM)

Elaborate study on properties, Composition and processing techniques of advanced materials, Layout of advanced processing techniques, classification, application and importance, Additive manufacturing, 3D metal printing, laser and electron beam processing, vacuum induction, electro-slag, vacuum arc, and controlled atmosphere processing.

Joining technologies for space and aerospace: EBW, Diffusion bonding, vacuum brazing, friction based joining techniques, atmosphere controlled joining of aero engine components, heavy alloy powder processing, functionally gradient materials

Aero-structures and nuclear power plant structural study, design of material for the same

TEXT BOOK/ REFERENCES:

1. Polmear, I. J., Light Alloys: From Traditional Alloys to Nanocrystals, 4th ed., Elsevier .
2. Reed, R. C., The Superalloys: Fundamentals and Applications, Cambridge Univ. Press
3. J.A. Dantzig, C.L. Tucker, Modelling in Materials Processing, 1st ed., Cambridge University Press, 2001.
4. Dr. Horst Buhl,, Advanced Aerospace Materials (Materials Research and Engineering), ISBN: 978-3-642-50161-6 (Print) 978-3-642-50159-3 (Online), 1992.
5. Material science and engineering, Vol III, aerospace and space materials, M Peter and C Leyens, EOLSS, UNESCO