GURU KASHI UNIVERSITY

Master of Technology in Mechanical Engineering

PG Curriculum (Appendix-III)

Session: 2025-26

Faculty of Engineering & Technology

Graduate Attributes of the Programme: -

Type of learning outcomes	**The Learning Outcomes Descriptors**
Graduates should be able to demonstrate the acquisition of:	
Learning outcomes that are specific to disciplinary/interdisciplinary areas of learning	The programme focuses on higher education and research activities, with the aim of emerging as leaders in engineering, management, applied research. The programme focuses to understand, analyse, develop and efficiently solve problems related to computer-based systems.
Generic learning outcomes	The generic learning outcomes for graduates typically include: Problem Analysis, Design and Development, Modern Tool Usage, Lifelong Learning
	1.Apply the knowledge of mechanical engineering tools and an engineering specialization to the solution of complex engineering problems 2. Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences. 3. Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. 4. Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations. 5. Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice. 6. Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development. 7. Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

	8. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings. 9.Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions 10. Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments. 11. Life-long learning**:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme learning outcomes: A Master Degree in Vocational (M. Voc. ME PROGRAMME) is awarded to students who have demonstrated the achievement of the outcomes located at level 6.5:

Element of the Descriptor	**Programme learning outcomes relating to Master Degree Programme(M.Tech ME)**
The Post graduates should be able to demonstrate the acquisition of:	
Knowledge and understanding	An M.Voc. in ME provides an in-depth understanding of advanced Mechanical Engineering concepts, preparing students for research, industry, and innovation.
	To Understand Entrepreneurial & Industry Readiness
General, technical and professional skills required to perform and accomplish tasks	Ability to analyse complex problems and devise effective solutions. Staying updated with emerging technologies and industry trends.
Application of knowledge and skills	. Graduates Equip with advanced knowledge and skills, enabling them to excel in various professional and research-oriented role.
Generic learning outcomes	Expertise in mechanical engineering concepts and their application
Constitutional, humanistic, ethical, and moral values	To apply moral ethics to perform research based activities.
Employability and job-ready skills, and entrepreneurship skills and capabilities/qualities and mindset	Proficiency in cloud platforms, software project management research based projects.
Credit requirements	44
Entry requirements	A student with a Bachelor Degree subject to fulfilment of the eligibility conditions of a programme as specified by the University, shall be eligible for admission to a 2-year PG Programme.

Program Structure

Semester: 1st									
Course Code	**Course Title**	**Type of Course**	**L**	**T**	**P**	**Credits**	**Int**	**Ext**	**Total Marks**
MME1450	Advance Manufacturing Processes	Major Course	4	0	0	4	30	70	100
MME1500	Advanced Heat and Mass Transfer	Major Course	3	1	0	4	30	70	100
MME1501	Optimization Techniques	Major Course	3	1	0	4	30	70	100
MME1451	Advanced Engineering Software Lab	Practicum Course (PC)	0	0	8	4	30	70	100
MME1502	Entrepreneurship Development	Skill Course	2	0	0	2	30	70	100
Discipline Elective-I (Any one of the following)									
MME1503	Computer Integrated Manufacturing	Discipline-Specific Elective	4	0	0	4	30	70	100
MME1504	Cogeneration & Waste Heat Recovery Systems								
MME1505	Design against Fatigue and Fracture								
Total			**15**	**3**	**8**	**22**	**180**	**420**	**600**

Semester: 2nd									
Course Code	**Course Title**	**Type of Course**	**L**	**T**	**P**	**Credits**	**Int**	**Ext**	**Total Marks**
MME2550	Materials Technology	Major Course	4	0	0	4	30	70	100
MME2551	Welding Technology	Major Course	4	0	0	4	30	70	100
MME2552	Mechatronics	Major Course	4	0	0	4	30	70	100
MME2553	Project Work	Practicum Course (PC)	0	0	8	4	30	70	100
MME2554	English for Research Paper Writing	Skill Course	2	0	0	2	30	70	100
Discipline Elective-II (Any one of the following)									
MME2555	Design Of Optimization Of Thermal System	Discipline-Specific Elective	4	0	0	4	30	70	100
MME2556	Theory of Cutting & Machine Tool Design								
MME2557	Industrial Tribology								
Total			**18**	**0**	**8**	**22**	**180**	**420**	**600**

Programme learning outcomes: A Master Degree (M. Tech ME PROGRAMME) is awarded to students who have demonstrated the achievement of the outcomes located at level 7:

Element of the Descriptor	**Programme learning outcomes relating to Master Degree Programme(M.Tech ME)**
The Post graduates should be able to demonstrate the acquisition of:	
Knowledge and understanding	An M.Tech in ME provides an in-depth understanding of advanced Mechanical Engineering concepts, preparing students for research, industry, and innovation.
	To Understand Entrepreneurial & Industry Readiness
General, technical and professional skills required to perform and accomplish tasks	Ability to analyse complex problems and devise effective solutions. Staying updated with emerging technologies and industry trends.
Application of knowledge and skills	. Graduates Equip with advanced knowledge and skills, enabling them to excel in various professional and research-oriented role.
Generic learning outcomes	Expertise in mechanical engineering concepts and their application
Constitutional, humanistic, ethical, and moral values	To apply moral ethics to perform research based activities.
Employability and job-ready skills, and entrepreneurship skills and capabilities/qualities and mind-set	Proficiency in cloud platforms, software project management research based projects.
Credit requirements	88
Entry requirements	A student with a Bachelor Degree subject to fulfilment of the eligibility conditions of a programme as specified by the University, shall be eligible for admission to a 2-year PG Programme.

Semester: 3rd									
Course Code	**Course Title**	**Type**	**L**	**T**	**P**	**Credits**	**Int**	**Ext**	**Total Marks**
MME3600	Research Methodology	Major Course	3	1	0	4	30	70	100
MME3601	Quality Assurance & Reliability Engineering	Major Course	3	1	0	4	30	70	100
MME3602	Dissertation Phase-1	Dissertation	-	-	-	12	30	70	100
MME3603	Organizational Behaviour	Skill Course	2	0	0	2	30	70	100
Total			**8**	**2**	**0**	**22**	**120**	**280**	**400**

Semester: 4th									
Course Code	**Course Title**	**Type of Course**	**L**	**T**	**P**	**Credits**	**Int**	**Ext**	**Total Marks**
MME4650	Dissertation Phase-II	Dissertation	-	-	-	12	30	70	100
MME4651	Seminar	Seminar	0	0	4	2	30	70	100
Discipline Elective-V(Any one of the following)									
MME4652	Combustion Engineering	Discipline-Specific Elective	4	0	0	4	30	70	100
MME4653	Vibration Analysis								
MME4654	Advanced Material Characterization Techniques								
Discipline Elective-VI(Any one of the following)									
MME4655	Advanced Thermodynamics	Discipline-Specific Elective	4	0	0	4	30	70	100
MME4656	Design of Experiments								
MME4657	Jig Fixture and Die Development								
Total			8	0	4	22	180	280	400
			49	**5**	**20**	**88**			

SEMESTER: I

Course Title: Advance Manufacturing Process
Course Code: MME1450

L	T	P	Credits
4	0	0	4

Total Hours-60

Learning Outcomes: After successful completion of this course, the students will be able to

1. Explain the evolution, classification and need of non-traditional machining technology in modern manufacturing
2. Compare and demonstrate the process principle and physical description; understand the parametric effect on process performance; solve problems related to process modelling, selection and material removal mechanics of mechanical energy based proc.
3. Predict and demonstrate the process principle and physical description; understand the parametric effect on process performance; solve problems related to process modeling, selection and material removal mechanics of thermal and electro-thermal energy based processes
4. Apply the latest developments in the applications of nontraditional hybrid machining processes
5. Understand the different types of advanced machining processes

Course Content

Unit I **15 hours**

Introduction:

Overview of general trends in Manufacturing, concept and significance of important properties related to manufacturing processes, limitations of conventional manufacturing processes need and evolution of advanced manufacturing, selection and economics of manufacturing processes.

Unit II **15 hours**

Advanced Machining Processes:

Classification, Review of conventional machining processes, Principles, process parameters, capabilities and mechanism of material removal of AJM, WJM, AWJM, USM

Electro Chemical Type Advanced Machining Processes:

ECM-Process principle, mechanism of material removal; Kinematics and dynamics of ECM; Tooling design; Choice and analysis of process parameters; Surface finish and accuracy.

Unit III **15 hours**

Thermal Type Advanced Machining Processes:

EDM, LBM and EBM processes: Working principle; Power circuits; Mechanism of material removal; Process parameters and characteristics; Surface finish and accuracy: Shape and materials applications, limitations.

Unit I V **15 hours**

Derived and Hybrid Advanced Machining Processes:

Introduction of processes like rotary ultra-sonic machining, electro stream drilling, shaped tube electro machining, wire electro discharge machining, electro chemical grinding, electro chemical honing, electro chemical deburring and electrochemical spark machining.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings:

- *Shan, H. S & Pandey, P.C. (1993). Modern Machining Processes, Tata Mc Hill N. Delhi*
- *Kalpakjian, S and Steven, R. S (2001).Manufacturing Processes for Engg. Materials,. Pearson Education*
- *G.F Benedict. (1987). Non Traditional manufacturing. Marcel Dekker New York,*
- *Mishra, P.K. (1997). Non-Conventional Machining. Narosa Publishing House N. Delhi*

Course Title: Advanced Heat and Mass Transfer
Course Code: MME1500

L	T	P	Credits
3	1	0	4

Total Hours-60

Learning Outcomes: After successful completion of this course, the students will be able to

1. Understand both the physics and the mathematical treatment of the advanced topics pertaining to the modes of heat transfer.
2. Understand physical and mathematical aspects of mass transfer.
3. Predict the concepts of radiation heat transfer for enclosure analysis
4. Analyze free and forced convection problems involving complex geometries with proper boundary conditions
5. Apply principles of heat transfer to develop mathematical models for uniform and non-uniform fins.

Course Content

Unit-I

Conduction **15 hours**

General heat conduction equation in rectangular, polar and spherical co-ordinates, one dimensional heat conduction, variable thermal conductivity, composite walls, elementary cases of two dimensional heat conduction, critical insulation thickness, unsteady heat conduction, heat transfer from extended surfaces, numerical methods.

Unit-II

Radiation **15hours**

Introduction, properties and definitions, review of radiation principles (Planck's law, Kirchoff's law, Stefan Boltzman law, Lambert's cosine law).Radiation through non-absorbing media; Hottel's method of successive reflections; Radiation through absorbing media; logarithmic decrement of radiation; apparent absorptivity of simple shaped gas bodies; net heat exchange between surfaces separated by absorbing medium; radiation of luminous gas flames.

Unit-III Convection **15 hours**

Heat transfer in laminar flow; free convection between parallel plates; forced internal flow through circular tubes; fully developed flow; velocity and thermal entry lengths; solutions with constant wall temperature and with constant heat flux; forced external flow over a flat plate; the two dimensional velocity and temperature boundary layer equations; Karman Pohlhousen approximate integral method. Heat transfer in turbulent flow; eddy heat diffusivity;

Unit-IV Mass Transfer **15 hours**

Introduction, concentration, velocities and fluxes, Fick's law of diffusion, steady state diffusion in common geometries, equimolal counter-diffusion in gases, steady state diffusion in liquids, transient mass diffusion in common geometries, mass transfer coefficient, convective mass transfer

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Eckert, E. R. G., & Drake Jr, R. M. (1987). Analysis of heat and mass transfer.*
- *Grober, Erk and Grigul (1989). Fundamentals of Heat Transfer. McGraw Hill*
- *Holman, J. P. (2008). Heat Transfer (Si Units) Sie. Tata McGraw-Hill Education.*
- *Schneider, P. J. (1955). Conduction heat transfer. Addison-Wesley Publishing Company.*
- *Howell, J. R., Siegel, R., &Mengüç, M. P. (1969). Thermal radiation heat transfer. Boca Raton, FL, USA: National Aeronautics and Space Administration.6. Rohsenhow and Choi Heat, Mass and Momentum Prentice Hall*

Course Title: Optimization Techniques
Course Code: MME1501

L	T	P	Credits
3	1	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1 Understand the fundamental knowledge of Linear Programming and Dynamic Programming problems.
2 Apply the classical optimization techniques and numerical methods of optimization.
3 Comprehend the basics of different evolutionary algorithms.
4 Enumerate fundamentals of Integer programming technique and apply different techniques to solve various optimization problems arising from engineering areas.
5 Optimize the industrial process management.

Course Content

Unit-I **15 hours**

Definition of Optimization:

Meaning of Operations Research, Modeling in operation research, principles of modeling, Introduction to linear and non-linear programming problems and formulation of problems.

Linear Programming:

Modeling of linear programming problem – a few examples; Solution of linear programming problem – simplex method, two-phase method, M-method; Sensitivity analysis – graphical approach

Unit –II **15 hours**

Transportation Model:

Transportation problem, Vogel's approximation method for finding feasible solution in transportation, methods for finding optimal solution, degeneracy in transportation problems, maximization in transportation problems.

Assignment Model:

Definition of assignment model, comparison with transportation problems, Hungarian method to find optimal solution, travelling salesman problems, branch and bound method.

Unit –III **15 hours**

Queuing Theory:

Types of queuing situation: Queuing models with Poisson's input and exponential service, their application to simple situations.

Dynamic Programming:
Deterministic and Probabilistic Dynamic programming

Unit-IV **15 hours**

CPM & PERT:
Network situations where PERT & CPM can be applied, planning, scheduling & control, work breakdown structure, Similarity and differences of CPM and PERT
Game theory: Two-person, Zero-sum games, Games with mixed strategies, Graphical solution, Solution by linear programming.

Transaction Mode
Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Rao, S.S. (1944). Engineering Optimization Theory and Practice. New Age International*
- *Kalyanmoy, D. (2014). Optimization for Engineering Design, PHI*
- *Arora, J.S. (1979). Optimization Techniques. John Wiley*

Course Title: Advanced Engineering Software Lab
Course Code: MME1451

L	T	P	Credits
0	0	8	4

Total Hours-120

Course Content

CAD/CAM: 2D and 3D geometric transformation, Composite Transformation, Projections; Curves: Cubic, Bezier, Splines; Surfaces: Quadric, Coons patch, Super Quadric, Bezier, B-Splines. Process planning, CL data generation, Automatic CNC code generation.

FEM: Solid model creation, different types of elements, chunking of model, meshing, mesh quality, different kinds of analysis: static, dynamic, transient, thermal, electro-magnetic, acoustics, sub structuring and condensation, Error and convergence. Non-linear static and dynamic analysis, contact analysis, multi-physics problem, rigid body analysis of flexible element.

CFD: Different types of CFD techniques, various stages of CFD techniques (i) pre-processor: governing equations, boundary conditions, grid generation, different discretization techniques (ii) processor: solution schemes, different solvers (iii) post-processing: analysis of results, validation, grid independent studies etc. Developing codes using commercial/open source software for solving few problems of laminar and turbulent flow with heat transfer applications. Engineering software's related to CAD/CAM, FEM, CFD, with both GUI and script like languages, are to be used for laboratory assignments

Suggested Readings

- *D. F. Rogers and J. A. Adams, "Mathematical Elements for Computer Ggraphics", McGrawHill, 1990*
- *2. M. Groover and E. Zimmers, "CAD/CAM: Computer-Aided Design and Manufacturing",*
- *Pearson Education, 2009.*
- *3. A. Saxena and B. Sahay, "Computer Aided Engineering Design", Springer, 2007.*
- *4. J. N. Reddy, "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill, 2005.*
- *J. Fish, and T. Belytschko, "A First Course in Finite Elements", 1st Ed., John Wiley and Sons,*
- *2007.*
- *J. D. Anderson, "Computational Fluid Dynamics", McGraw-Hill Inc. (1995).*

- *H. K. Versteeg and W. Malalaskera, "An Introduction to Computational Fluid Dynamics",*
- *Dorling Kindersley (India) Pvt. Ltd. (2008).*
- *S. Biringen and C Chow, An Introduction to Computational Fluid Mechanics by Example*

Course Title: Entrepreneurship Development
Course Code: MME1502

L	T	P	Credits
2	0	0	0

Total Hours-30

Learning Outcomes: On the successful completion of this course, the students will able to.

1. Enable the students to understand the concept of Entrepreneurship and
2. Learn the professional behavior expected of an entrepreneur.
3. Identify significant changes and trends which create business opportunities
4. Analyze the environment for potential business opportunities.
5. 3. Provide conceptual exposure on converting idea to a successful entrepreneurial firm.

Unit-I: 6hrs

Entrepreneurship: Entrepreneur characteristics – Classification of Entrepreneurships – Incorporation of Business – Forms of Business organizations –Role of Entrepreneurship in economic development – Start-ups.

Unit-II: 6hrs

Idea Generation and Opportunity Assessment: Ideas in Entrepreneurships – Sources of New Ideas – Techniques for generating ideas – Opportunity Recognition – Steps in tapping opportunities.

Unit-III: 10 hrs

Project Formulation and Appraisal: Preparation of Project Report –Content; Guidelines for Report preparation – Project Appraisal techniques –economic – Steps Analysis; Financial Analysis; Market Analysis; Technical Feasibility. Unit-iv: Institutions Supporting Small Business Enterprises: Central level Institutions: NABARD; SIDBI, NIC, KVIC; SIDIO; NSIC Ltd; etc. – state level Institutions –DICs- SFC- SSIDC- Other financial assistance.

Unit-V: 8hrs

Government Policy and Taxation Benefits: Government Policy for SSIs- tax Incentives and Concessions –Non-tax Concessions –Rehabilitation and Investment Allowances.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested reading

- *Arya Kumar, Entrepreneurship, Pearson, Delhi, 2012.*
- *Poornima M.CH., Entrepreneurship Development –Small Business Enterprises, Pearson, Delhi,2009*
- *Michael H. Morris, ET. al., Entrepreneurship and Innovation, Cen gage Learning, New Delhi, 2011*
- *KanishkaBedi, Management and Entrepreneurship, Oxford University Press, Delhi, 2009*
- *Anil Kumar, S., ET.al., Entrepreneurship Development, New Age International Publishers, New Delhi, 2011*
- Khanka, SS, Entrepreneurship Development, S. Chand, New Delhi.
- Peter F. Drucker,Innovation and Entrepreneurship.
- A.Sahay, M. S. Chhikara, New Vistas of Entrepreneurship: Challenges & Opportunities.

Course Title: Computer Integrated Manufacturing
Course Code: MME1503

L	T	P	Credits
4	0	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1. Understand CAD, CAM, CIM, and automation in manufacturing.
2. Apply production planning, CAPP, MRP, and inventory control.
3. Analyze cellular manufacturing, part classification, and machine cell design.
4. Evaluate FMS, AGVS, and their applications in automation.
5. Explore industrial robotics, control systems, and programming.

Course Content

UNIT I **12 hrs**

INTRODUCTION

Brief introduction to CAD and CAM – Manufacturing Planning, Manufacturing control Introduction to CAD/CAM – Concurrent Engineering - CIM concepts – Computerised elements of CIM system –Types of production - Manufacturing models and Metrics – Mathematical models of Production Performance – Simple problems – Manufacturing Control – Simple Problems – Basic Elements of an Automated system – Levels of Automation – Lean Production and Just-In Time Production.

UNIT II **12 hrs**

PRODUCTION PLANNING AND CONTROL AND COMPUTERISED PROCESS PLANNING

Process planning – Computer Aided Process Planning (CAPP) – Logical steps in Computer Aided Process Planning – Aggregate Production Planning and the Master Production Schedule – Material Requirement planning – Capacity Planning- Control Systems-Shop Floor Control Inventory Control – Brief on Manufacturing Resource Planning-II (MRP-II) & Enterprise Resource Planning (ERP) - Simple Problems. Syllabus

UNIT III **12 hrs**

CELLULAR MANUFACTURING

Group Technology (GT), Part Families – Parts Classification and coding – Simple Problems in Opitz Part Coding system – Production flow Analysis – Cellular Manufacturing – Composite part concept – Machine cell design and layout – Quantitative analysis in Cellular Manufacturing – Rank Order

Clustering Method - Arranging Machines in a GT cell – Hollier Method – Simple Problems.

UNIT IV **12 hrs**

FLEXIBLE MANUFACTURING SYSTEM (FMS) AND AUTOMATED GUIDED VEHICLE SYSTEM (AGVS)

Types of Flexibility - FMS – FMS Components – FMS Application & Benefits – FMS Planning and Control– Quantitative analysis in FMS – Simple Problems. Automated Guided Vehicle System (AGVS) – AGVS Application – Vehicle Guidance technology – Vehicle Management & Safety. Syllabus

UNIT V **12 hrs**

INDUSTRIAL ROBOTICS

Robot Anatomy and Related Attributes – Classification of Robots- Robot Control systems – End Effectors – Sensors in Robotics – Robot Accuracy and Repeatability - Industrial Robot Applications – Robot Part Programming – Robot Accuracy and Repeatability – Simple Problems.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning

Suggested reading

- *Mikell.P.Groover "Automation, Production Systems and Computer Integrated Manufacturing", Prentice Hall of India, 2008.*
- *Radhakrishnan P, Subramanyan S.and Raju V., "CAD/CAM/CIM", 2nd Edition, New Age International (P) Ltd, New Delhi, 2000.*

Course Title: Cogeneration & Waste Heat Recovery Systems
Course Code: MME1504

L	T	P	Credits
4	0	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1. To detail on the importance of Total Energy Concept, its advantages, cost effectiveness
2. To analyse the basic energy generation cycles
3. To detail about the concept of cogeneration, its types and probable areas of applications
4. To study the significance of waste heat recovery systems and carry out its economic analysis Course outcomes.
5. Understand the Economic aspects of cogeneration and Waste heat recovery

UNIT-I **12 hrs**

Introduction: Principles of thermodynamics – cycles – topping – bottoming – combined cycle – organic Rankine cycles – performance indices of cogeneration systems – waste heat recovery – sources and types – concept of tri generation.

UNIT-II **12 hrs**

Co-Generation Technologies: Configuration and thermodynamic performance – steam turbine co-generation systems – gas turbine cogeneration systems – reciprocating IC engines cogeneration systems – combined cycles cogeneration systems – advanced cogeneration systems: fuel cell, Stirling engines etc.,

UNIT-III **12 hrs**

Issues and Applications of Cogeneration Technologies: Cogeneration plants electrical interconnection issues – utility and cogeneration plant interconnection issues – applications of cogeneration in utility sector – industrial sector – building sector – rural sector – impacts of cogeneration plants – fuel, electricity and environment.

UNIT-IV **12 hrs**

Waste Heat Recovery Systems: Selection criteria for waste heat recovery technologies – recuperators – Regenerators – economizers – plate heat exchangers – thermic fluid heaters – Waste heat boilers – classification, location, service conditions, design Considerations – fluidized bed heat

exchangers – heat pipe exchangers – heat pumps – sorption systems. MLR Institute of Technology

UNIT-V **12 hrs**

Economic Analysis: Investment cost – economic concepts – measures of economic performance – procedure for economic analysis – examples – procedure for optimized system selection and design – load curves – sensitivity analysis – regulatory and financial frame work for cogeneration and waste heat recovery systems.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning

Suggested reading

- *Charles H. Butler, Cogeneration, McGraw Hill Book Co.,*
- *EDUCOGEN – The European Educational tool for cogeneration, Second Edition, 2001*
- *Horlock JH, Cogeneration - Heat and Power, Thermodynamics and Economics, Oxford, 1987.*
- *Institute of Fuel, London, Waste Heat Recovery, Chapman & Hall Publishers, London, 1963.*
- *Seagate Subrata, Lee SS EDS, Waste Heat Utilization and Management, Hemisphere, Washington, 1983.*
- *De Nevers, Noel, Air Pollution Control Engineering, Mc Graw Hill, New York, 1995*

Course Title: Design against Fatigue and Fracture	L	T	P	Credits
Course Code: MME1505	4	0	0	4

Total Hours-60

Learning Outcomes: On completion of this course, the successful students should be able to

1 Understand the major concepts of fracture mechanisms and fracture modes associated with failure

2 Have a fundamental understanding of various regimes of fatigue crack growth and life estimation

3 Analyse the fatigue failure of aircraft components made up of metals and composites

4 Conduct case study to understand the impact of fracture mechanics in design and life prediction of aircraft components

UNIT-I **12 hrs**

Fatigue Of Structures Classes Introduction to fatigue, Endurance limits - Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams - Notches and stress concentrations - Neuber's stress concentration factors - Plastic stress concentration factors - Notched S.N. Curves.

UNIT-II **12 hrs**

Physical Aspects of Fatigue

Phase in fatigue life - Crack initiation - Crack growth - Final fracture - Dislocations - Fatigue fracture surfaces.

UNIT-III **12 hrs**

Statistical Aspects of Fatigue Behaviour

Classes- Low cycle and high cycle fatigue - Coffin - Manson's relation - Transition life - Cyclic strain hardening and softening - Analysis of load histories - Cycle counting techniques -Cumulative damage - Miner's theory.

UNIT-IV **12 hrs**

Overview of Engineering Fracture Mechanics

Strength of cracked bodies - Potential energy and surface energy - Griffith's theory - Irwin - Orwin extension of Griffith's theory to ductile materials - Stress analysis of cracked bodies - Effect of thickness on fracture toughness.

UNIT-V Fatigue Design And Testing **12 hrs**

Safe life and fail-safe design philosophies, Importance of fracture mechanics in aerospace structure, Application to structures

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning

Suggested reading

- *Prashant Kumar, "Elements of Fracture Mechanics", Tata McGraw Hill, New Delhi, India, 2009.*
- *Ali Fatemi, "Metal Fatigue in Engineering", 2nd edition, John Wiley and sons, inc., 2000.*
- *K. R.Y. Simha, "Fracture Mechanics for Modern Engineering Design", Universities Press (India) Limited, 2001*
- *4 T.L. Anderson, "Fracture Mechanics - Fundamentals and Applications", 3rd Edition, Taylor and Francis Group, 2005.*
- *K. Ramesh, e-Book on "Engineering Fracture Mechanics", IIT Madras, 2007.*

SEMESTER: II

Course Title: Material Technology	L	T	P	Credits
Course Code: MME 2550	4	0	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1 Understand the different structural materials for various engineering applications based on their properties for best performance under the specified conditions.
2 Specify property degradation and different modes of failure of materials during their application in different working environments and can suggest suitable surface modification techniques.
3 Examine non-destructive testing techniques for flaw detection in materials
4 Apply new knowledge as needed, using appropriate learning strategies
5 Develop and conduct appropriate experimentation, analyze and interpret data.

Course Content

Unit-I **15 hrs**

Introduction:

Introduction to material science & engineering, Classification of engineering materials, Properties of materials, Crystal geometry and structure determination.

Mechanical Properties & Testing of Materials:

Fundamental mechanical properties, creep, fatigue and fracture processes, Factors effecting mechanical properties, destructive and non-destructive testing of materials.

Unit –II **15 hrs**

Metals and Alloys:

Ferrous and non-ferrous metals, alloy system, solid solutions, Phase diagram, phase transformation, iron-carbon system, isothermal transformation – TTT diagram, Heat treatment of plain carbons steels, low alloy steels stainless steel, aluminium alloys, copper alloys and.

Ceramic Materials:

Introduction, Simple ceramic crystal structure, silicate structure, mechanical properties of ceramics.

Unit –III **15 hrs**

Polymer Materials:

Polymer, broad classification, basic concept of polymer science, mechanical properties of polymers, reinforced polymers, manufacturing processes of polymer.

Nano Structural Materials:

Production methods for Carbon Nano Tubes (CNT), Properties of CNT, Advantages of Nano-materials.

Unit IV **15 hrs**

Composite Materials:

Introduction, Characteristics of particles, reinforced and fibre reinforced composites.

Deterioration of Materials:

Oxidation and Corrosion, Corrosion control and corrosion resistance of alloys Wear and Erosion, effect of porosity and hardness on degradation of materials.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Sidney, H. A. (1964). Introduction to Physical Metallurgy, Mc-GrawHill, N. York.*
- *Donald, R. A & Pradeep, P. P. (2002). The science and Engineering of Materials, Thomson.*
- *Raghavan,V. (2008). Material Science & Engineering. Prentice-Hall of India (P), N. Delhi*
- *William F. Smith. (1996). Principles of Materials Science and Engineering, Mc-Graw Hill.*
- *Shirvastav, D.P.K (1995). Non-Destructive Testing Techniques. Mc-Graw Hill.*
- *Jena, A.K. &Chaturvedi, M.C. (1992). Phase Transformations in Materials. Prentice Hall.*

COURSE TITLE: Welding Technology	L	T	P	Credits
COURSE CODE: MME2551	4	0	0	4

Total Hours-60

Learning Outcomes: After successful completion of this course, the students will be able to

1. Analyses metallurgical changes exist in weld metal and its effect on properties
2. Comprehend the purpose and classification of coating of the electrodes
3. Understand the various types of modes of metal transfer exist in welding processes.
4. Examine the difference between various welding processes and its industrial utilization.
5. Predict theory and mechanism of solid state welding

Course Content

Unit-I **15 hrs**

Basic classification of welding processes, weldability, weld thermal cycle, metallurgy of fusion welds, solidification mechanism and micro structural products in weld metal, epitaxial, cellular and dendritic solidification, metallurgical changes in weld metal, phase transformation during cooling of weld metal in carbon and low alloy steel, prediction of microstructures and properties of weld metal. Heat affected zone, re-crystallization and grain growth of HAZ, gas metal reaction, effects of alloying elements on welding of ferrous metals.

Unit-II **15 hrs**

Arc welding power sources, basic characteristics of power sources for various arc welding processes, duty cycles, AC/DC welding power source, DC rectifiers, thyristor controlled rectifiers, transistorized units, inverter systems. Arc efficiency, temperature distribution in the arc, arc forces, arc blow, electrical characteristics of an arc, mechanism of arc initiation and maintenance, role of electrode polarity on arc behaviour and arc stability, analysis of the arc. Arc length regulation in mechanised welding processes.

Unit-III **15 hrs**

Critical reviews of manual metal arc welding (MMAW) GTAW, GMAW, FCAW and CO welding processes, plasma arc, submerged arc welding, electro gas and electro slag welding, analysis of the process. Electrode coatings, classification of coatings of electrodes for SMAW, SAW fluxes, role of flux ingredients and shielding gases, classification of solid and flux code wires.

Unit-IV **15 hrs**

Theory and mechanism of solid state welding. Techniques and scope of friction welding, diffusion welding, cold pressure welding and ultrasonic welding. High energy rate welding. Analysis of the Process. Technique, scope and application of the electron beam and laser welding processes. Under water welding - process & problem.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Parmar, R.S. (1996). Welding processes & Technology. Khanna Publishers.*
- *Nandkarni, S.V. (1998). Modern Arc Welding Technology. Oxford & IDH publishing Co.*
- *Gourd, L.M. (1980). Principles of Welding Technology, ELBS/ Edward Arnold.*
- *Richard, L. Little. (1973). Welding & Welding Technology. Mc-Graw Hill.*
- *Rossi, B.E. (1954). Welding Technology. Mc-Graw Hill.*

COURSE TITLE: Mechatronics	L	T	P	Credits
COURSE CODE: MME2552	4	0	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1 Construct the block diagram of any physical mechatronics device used in day-to-day life.

2 Calculate the output to input relation of any physical model in the form of a transfer function.

3 Evaluate the performance of any physical system in terms of its performance parameters.

4 Develop the mathematical model of any physical model from any engineering domain.

5 Interface the sensors and actuators of a mechatronic device to the computer/laptop.

Course Content

Unit-I **15 hrs**

Introduction:

What is Mechatronics, Systems, Measurement Systems, Control Systems, Microprocessor- based controllers, The Mechatronics Approach.

Sensors Strain Gauge, Potentiometer, Optical Encoders:

Incremental and absolute encoders, Linear variable differential transformer (LVDT), Piezoelectric, Proximity sensor, Resistance Temperature Detector, (RTD), Thermistors, Thermocouple, Hall Effect sensor,

Unit-II **15 hrs**

Electronic Fundamentals:

Signal Conditioning Process, Operational Amplifier, Digital Logic, Logic Gates, Boolean algebra, Sequential Logic, Data Acquisition Systems, Measurement Systems, Testing and Calibration.

Precision Mechanical Actuation:

Pneumatic actuation systems, electro-pneumatic actuation systems, hydraulic actuation systems, electro-hydraulic actuation systems, mechanical systems, types of motion, kinematics, inverse kinematics, timing belts, ball screw and nut, linear motion guides,linearbearings,harmonictransmission,bearings,motor/driveselection.

Unit-III **15 hrs**

Electromechanical Drives:

Relays and solenoids, stepper motors, DC brushed and brushless motors, DC servo motors, AC / DC motors for non-servo motion drives, braking methods, pulse width modulated, Bipolar driver, Mosfet drives, SCR drives, variable frequency drives.

Microprocessor and Computers:
Introduction to 8085, Architecture, programming, I/O, Computer interfacing, Function of PLC, Architecture, Components of PLC, selection of PLC, Ladder Logic diagram, Logic functions: latching, sequencing, counters, shift registers, jumpers, manipulation of data, arithmetic operations

Unit IV **15 hrs**

Input/output Systems:
Interfacing, input / output ports, interface requirements, peripheral interface adapters, serial communication interface, direct memory access.

Control System:
System transfer function, Laplace transformation and its applications, continuous and discrete processes, proportional control, integral control, differential control, PID control, digital controllers, control system performance, controller tuning, adaptive control, frequency response, PLC, PMC, introduction to fuzzy logic and neural networks.

Transaction Mode
Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Kamm, L.J. (1996). Understanding of Electro-Mechanical Engineering-An Introduction to Mechatronics. Prentice-Hall of India.*
- *Koren, Y. (1983). Computer Control of Manufacturing system. McGrawHill.*
- *Groover, M.P. (2001). Production Systems and CIM,PHI.*
- *Maleki, R.A. (1991).Flexible Manufacturing systems. PrenticeHall.*
- *Kuo, B. C. (2003). Feedback Control Systems. PHI.*

Course Title: Project Work	L	T	P	Credits
Course Code: MME2553	0	0	8	4

Total hours: 120

Learning Outcomes: On the successful completion of this course, the students will able to

1. Apply engineering principles to real-world projects
2. Plan and monitor project tasks individually or as a team
3. Demonstrate practical experience in project execution
4. Communicate project findings clearly through reports and presentations

Course Content

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Course Title: English for Research Paper Writing	L	T	P	Credits
Course Code: MME2554	2	0	0	2

Total Hours-30

Learning Outcomes: After successful completion of this course, the students will be able to

1. Understand professional writing by studying management communication contexts and genres, researching contemporary business topics, analyzing quantifiable.
2. Examine the formal elements of specific genres of organizational communication: white papers, recommendation and analytical reports, proposals, memorandums, web pages, wikis, blogs, business letters, and promotional documents.
3. Understand how to critically analyze data from research; incorporate it into assigned writing clearly, concisely, and logically; and attribute the source with proper citation.
4. Comprehend the ethical, international, social, and professional constraints of audience, style, and content for writing situations

Course Content

Unit-I **8 Hours**

Planning and Preparation, Word Order, breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness.

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction

Unit-II **6 Hours**

Review of the Literature, Methods, Results, Discussion, Conclusions, the Final Check.

key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature,

Unit-III **8 Hours**

Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, and skills are needed when writing the Conclusions

Unit-IV **8 Hours**

Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Goldbort, R. (2008). Writing for science. Yale university press.*
- *Day, R. (2013). Bringing extensive reading into the classroom-Into the Classroom. Oxford University Press*
- *3Highman, N. (1998). Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book.*

Course Title: Design of Optimization of Thermal System	L	T	P	Credits
Course Code: MME2555	4	0	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1. Understand the basic concept of design and optimization relevant to thermal system.
2. Acknowledge, access and analysis various thermal systems used in engineering applications.

Unit-1 **15 hrs**

Introduction: Engineering Design, Design as Part of Engineering Enterprise, Design versus analysis, need for optimization, basic characteristics of thermal system, Formulation of the Design Problem, Steps in the Design Process, Computer-Aided Design

Unit-2 **15 hrs**

Modeling & Simulation of thermal systems: Basic considerations in design, importance of modeling in design, types of models, mathematical modeling, physical modeling and dimensional analysis, solution procedure, merging of different models, accuracy and validation, system simulation, curve fitting, methods of numerical simulation, numerical simulation versus real systems.

Unit-3 **20 hrs**

Optimization: Introduction, Formulation of optimization problems, Calculus techniques: Lagrange multiplier method, Search methods, Concept of interval of uncertainty, reduction ratio, reduction ratios of simple search techniques like exhaustive search, dichotomous search, Fibonacci search and Golden section search, numerical examples Method of steepest ascent/steepest descent, conjugate gradient method: examples, New generation optimization techniques: Genetic algorithm and simulated annealing, Introduction to Bayesian framework for optimization

Unit-4 **10 hrs**

Economic Considerations: Calculation of Interest, Worth of Money as a Function of Time, Series of Payments, Raising Capital, Taxes, Economic Factor in Design, Application to Thermal Systems, Carbon Credit Calculation

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Design and optimization of thermal systems, Y Jaluria, Mc Graw Hill.*
- *Elements of thermal fluid system design, L C Burmeister, Prentice Hall*
- *Essentials of Thermal System Design and Optimization, Prof. C Balaji, Ane Books, New Delhi in India and CRC Press in the rest of the world*
- *Design of thermal systems, W F Stoecker, Mc Graw Hill*
- *Introduction to optimum design, J S Arora, Mc Graw Hill*

Course Title: Theory of Cutting & Machine Design	L	T	P	Credits
Course Code: MME2556	4	0	0	4

Total Hours-60

Learning Outcomes: After successful completion of this course, the students will be able to

1. Understand Cutting forces, Chip formation, merchant's circle diagram and calculation.
2. Analyses metal Cutting machine Tools, Kinematics of machine tools and basic Principles of machine Tool Design.
3. Comprehend design considerations of electrical, mechanical and hydraulic drives in machine
4. Understand anti friction bearings and sliding bearings..
5. Predict automation, testing and Standardization for machine tools

Course Content

Unit-I **15 hrs**

Theory of Metal Cutting: Mechanism of metal cutting, Cutting forces, Chip formation, Merchant's circle diagram, Calculations, System of Tool nomenclature, Tool geometry, Machinability, Tool life, Cutting tool materials, Cutting fluids. Abrasive Machining- Mechanism of grinding, lapping and honing.

Introduction To Machine Tool Design: Introduction to Metal Cutting Machine Tools, Kinematics of machine tools, Basic Principles of machine Tool Design.

Unit-II **15 hrs**

Design of Drives: Design considerations of electrical, mechanical and hydraulic drives in machine tool, Selection of speeds and feeds, stepped and stepless regulation of speed, Estimation of power requirements and selection of motor for metal cutting machine tool spindles, design of gear box.

Design of Machine Tool Structures: Principles, materials, static & dynamic stiffness, Shapes of Machine tool Structures. Design of beds, columns, housings, tables, ram etc.

Unit-III **15 hrs**

Design of Spindles, Guideways and Slideways: Design of Machine tool Spindles- Materials of Spindles, machine tool Compliance. Design of Bearings- Anti friction bearings, sliding bearings. Design of guide ways and slideways.

Design of Control Mechanisms: Basic principles of control, mechanical, electrical, hydraulic, numeric and fluid controls, Selection of standard components, Dynamic measurement of forces and vibrations in machine tools, Stability against chatter, Use of vibration dampers.

Unit-IV **15 hrs**

Automation, Testing and Standardisation: Automation drives for machine tools, Degree of automation, Semi-automation, analysis of collet action, design of collet, bar feeding mechanism, tooling layout, single spindle mechanism, analysis, Swiss type automatic machine. Loading and unloading. Transfer-devices, Modulator-design concept, in process gauging. Acceptance tests and standardization of machine tools.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Juneja, B.L. &Sekhon, G.S, (1980). Fundamentals of metal cutting and machine tools. New Age International (P) Ltd., N. Delhi*
- *Shaw, M.C. (2000). Metal Cutting Principles. Oxford Clarendon Press.*
- *Bhattacharya, A.S. (2002). Metal Cutting Theory and Practice. New Central Book Agency(P) Ltd, Calcutta.*
- *Arshinov&Alelrev. (2004). Metal Cutting Theory and Cutting Tool Design. MIR Publishers, Moscow.*
- *Mehta, N.K. (1995). Machine Tool Design. Tata Mc-Graw Hill, N. Delhi*

Course Title: Industrial Tribology	L	T	P	Credits
Course Code: MME2557	4	0	0	4

Total Hours-60

Learning Outcomes: After successful completion of this course, the students will be able to
To develop a solution oriented approach by in depth knowledge of Industrial Tribology.
To address the underlying concepts, methods and application of Industrial Tribology.

Unit: I **15 hrs**

Introduction: Tribology in design, tribology in industry Viscosity, flow of fluids, viscosity and its variation absolute and kinematic viscosity, temperature variation, viscosity index determination of viscosity, different viscometers, Tribological considerations Nature of surfaces and their contact; Physic mechanical properties of surface layer, Geometrical properties of surfaces, methods of studying surfaces; Study of contact of smoothly and rough surfaces.

Friction and wear: Role of friction and laws of static friction, causes of friction, theories of friction, Laws of rolling friction; Friction of metals and non-metals; Friction measurements. Definition of wear, mechanism of wear, types and measurement of wear, friction affecting wear, Theories of wear; Wear of metals and non-metals.

Unit: II **17 hrs**

Hydrostatic lubrication: Principle of hydrostatic lubrication, General requirements of bearing materials, types of bearing materials., Hydrostatic step bearing, application to pivoted pad thrust bearing and other applications, Hydrostatic lifts, hydrostatic squeeze films and its application to journal bearing, optimum design of hydrostatic step bearing.

Hydrodynamic theory of lubrication: Principle of hydrodynamic lubrication, Various theories of lubrication, Petroff's equation, Reynold's equation in two dimensions -Effects of side leakage - Reynolds equation in three dimensions, Friction in sliding bearing, hydro dynamic theory applied to journal bearing, minimum oil film thickness, oil whip and whirl, anti –friction bearing, hydrodynamic thrust bearing.

Unit: III **18 hrs**

Air/gas lubricated bearing: Advantages and disadvantages application to Hydrodynamic journal bearings, hydrodynamic thrust bearings. Hydrostatic thrust bearings. Hydrostatic bearing Analysis including compressibility effect. Lubrication and lubricants: Introduction, dry friction; Boundary lubrication; classic hydrodynamics, hydrostatic and elasto hydrodynamic lubrication, Functions of lubricants, Types of lubricants and their industrial uses; SAE classification, recycling, disposal of oils, properties of liquid and grease lubricants; lubricant additives, general properties and selection.

Unit:IV **12 hrs**

Special Topics: Selection of bearing and lubricant; bearing maintenance, diagnostic maintenance of Tribological components and considerations in IC engines and automobile parts, roller chains and wire rope, lubrication systems; Filters and filtration

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Fundamentals of Tribology, Basu, SenGupta and Ahuja/PHI*
- *Tribology in Industry : Sushil Kumar Srivatsava, S. Chand &Co.*
- *Tribology H.G.Phakatkar and R.R.Ghorpade Nirali Publications*
- *Tribology – B.C. Majumdar, McGraw Hill Co Ltd.*
- *Standard Hand Book of Lubrication Engg., O'Conner and Royle, McGraw Hills C*
- *Introduction to Tribology, Halling , Wykeham Publications Ltd.*

SEMESTER: III

COURSE TITLE: Research Methodology
COURSE CODE: MME3600

L	T	P	Credits
4	0	0	4

Total Hours-60

Learning Outcomes: On the successful completion of this course, the students will able to

1 Examine various kinds of research, objectives of doing research, research process, research designs and sampling.
2 Predict basic knowledge on qualitative research techniques
3 Examine the scaling techniques as well as the quantitative data analysis
4 Predict data analysis-and hypothesis testing procedures
5 Organize and conduct research (advanced project) in a more appropriate manner

Course Content

UNIT-I **12 hrs**

Research: its concept, nature, scope, need and Objectives of Research, Research types, Research methodology, Research process – Flow chart, description of various steps, Selection of research problem.

UNIT-II **15 hrs**

Research Design: Meaning, Objectives and Strategies of research, different research designs, important experimental designs, Types of data collection and classification, Observation method, Interview Method, Collection of data through Questionnaires, Schedules, data analysis and interpretation, editing, coding, content analysis and tabulation

UNIT-III **17 hrs**

Sampling Methods:

Different methods of Sampling: Probability Sampling methods, Random Sampling, Systematic Sampling, Stratified Sampling, Cluster Sampling and Multistage Sampling. Non probability Sampling methods, Sample size.

UNIT-IV **15 hrs**

Introduction to Intellectual Property Rights: Concept & theories, Kinds of intellectual Property Rights, Advantages & Disadvantages of IPR, Development of IPR in India, Role & Liabilities of IPRs in India. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Panneerselvam, R , 'Research Methodology', PHI, New Delhi.*
- *Cooper, D.R.,Schindler,P.S., 'Business Research Methods,' Tata McGraw Hill*
- *Gupta S P,' Statistical Methods', Sultan Chand & Sons, Delhi*
- *Ronald E Walpole, 'Probability and Statistics for Engineers and Scientists' (International Edition) , Pearson Education.*
- *Geode, Millian J. & Paul K. Hatl, "Methods in Research", McGraw Hills, NewDelhi*
- *Kothari C.R., "Research Methodology", New AgePublisher*
- *Nargundkar R, Marketing Research, Tata McGraw Hill, New Delhi,2002.*
- *Sekran, Uma, "Business Research Method", Miley Education,Singapore*
- *Law Relating to Intellectual Property Rights" by V K Ahuja*
- *Intellectual Property Rights" by Neeraj Pandey and KhushdeepDharni*

Website/Links/Online Portal/ICT

- *https://www.academia.edu/*
- *https://www.studeersnel.nl*
- *https://www.scribd.com*

Course Title: Quality Assurance & Reliability Engineering	**L**	**T**	**P**	**Credits**
Course Code: MME3601	**3**	**1**	**0**	**4**

Total Hours - 60

On successful completion of this course, the students will able to

1. Understand the basic techniques of quality improvement, fundamental knowledge of statistics and probability
2. Analyze use control charts to analyze for improving the process quality
3. Examine the defective item analysis (type of defect, frequency, number of defects), the student manager will be able to draw and justify the Pareto chart to prioritize the defects
4. Comprehend the enlist and justify the four levels of benchmarking and/or enlist and brief seven step benchmarking model
5. Analysis the concepts of reliability and maintainability

Unit-I **15 hrs**

Quality and Total Quality Management, Excellence in manufacturing/service, factors of excellence, relevance of TQM, benefits of TQM. Concept and definition of quality, Total Quality Control (TQC) and Total Quality Management (TQM), salient features of TQC and TQM. Total Quality Management Models. Just-in-time (JIT): Definition: Elements, benefits, equipment layout for JIT system, Kanban system MRP (Material Requirement Planning) vs JIT system, Waste elimination, workers involvement through JIT: JIT cause and effect chain, JIT implementation, Role of JIT in lean manufacturing.

Unit-II **15 hrs**

Customer Satisfaction: data collection and complaint, redressal mechanism. Planning Process: Policy development and implementation, plan formulation and implementation. Process Management: Factors affecting process management, Quality function development (QFD), and quality assurance system.

Total Employees Involvement (TEI): Empowering employees: team building, quality circles, reward and Recognition, education and training, Suggestion schemes.

Unit-III **15 hrs**

Problems solving Defining problem, Problem identification and solving process, QC tools. Benchmarking definition, concept, process and types of bench marking.

Unit-IV **15 hrs**

Quality Systems: Concept of quality system standards: relevance and origin of ISO 9000, Benefits, Elements of ISO 9001, ISO 9002, ISO 9003. Advanced techniques of TQM: Design of experiments: failure mode effect analysis: Taguchi methods

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning.

Suggested Readings

- *Satpathy, D., & Chandra, K. (2003). Total Quality Management (TQM) in the Era of Globalization. In 21st Annual Convention and Conference Society for Information Science.*
- *Zairi, M. (2013). The TQM legacy – Gurus' contributions and theoretical impact. The TQM Journal.*
- *YEAR, B. T. S. University College of Engineering.*
- *Rezic, S., Visekruna, V., & Majstorovic, V. (2007). Planning and quality management framework at University of Mostar. Annals of DAAAM & Proceedings*

Course Title: Dissertation Phase-1
Course Code:MME3603

L	T	P	Credits
-	-	-	12

Learning Outcomes: On successful completion of this course, students will be able to:

1. Get deep insights to collect, review and analyze the related literature.
2. To apply the knowledge to formulate hypothesis & design research process.
3. Find the research titles which are significant, applicable and researchable.
4. Interpret the findings to design statistical strategies & write references,

Course Content

A research proposal contains all the key elements involved in the research process and proposes a detailed information to conduct the research. The students are supposed to prepare the research proposal of any research area of their choice following these steps:

1. Selection of topic
2. Significance of the research area
3. Formulation of hypothesis/Research questions
4. Review of related literature
5. Method & Procedure (Includes sampling & design)
6. Data collection and proposed statistical analysis
7. Delimitations
8. Reference/Bibliography.

Evaluation

The students will have to complete the writing process of each topic given above within one week, which will be evaluated at the end of every week. It will consist of 8 marks each. The final proposal shall be of 15 marks, Viva 16marks and attendance 5 marks**.**

Transaction Mode

Collaborative learning, Group Discussion, E team Teaching, Activities, Assessments, Collaborative teaching, Peer Teaching, Video Based Teaching, Quiz, Open talk, E team Teaching, Case analysis, Flipped Teaching

Course Title: Organizational Behaviour
Course Code: MME3603

L	T	P	Credits
2	0	0	2

Total hours: 30

Learning Outcomes: On successful completion of this course, students will be able to:

1. Understand Organizational Behavior (OB) frameworks, management principles, and key behavioral sciences.
2. Apply motivation theories (e.g., Maslow, Herzberg) and evaluate personalities/perceptions in organizational contexts.
3. Analyze individual/group behavior's impact on organizational goals and employ stress/people management strategies.
4. Compare leadership styles (transformational, transactional) and resolve conflicts to align with organizational objectives.
5. Cultivate positive work culture/climate by balancing extrinsic/intrinsic factors for work-life harmony.

Course Content

Unit 1 **6 hrs**

Introduction to Organizational Behaviour : Management and Organizational Behaviour, Theories of Management, Major Behavioural Science that contribute to Organizational Behaviour-Psychology, Sociology, Socio-Psychology, Political Science, Anthropology, Organizational structure, Dynamics of People and Organization, Models of Organizational Behaviour, Hawthorne studies, Challenges and opportunities in Organizational Behaviour.

Unit 2 **6 hrs**

Motivation, Personality & Perception: Motivation-Motivation and Behaviour, theories of Motivation, Reinforcement theory, Organisational Learning Process, Motivation and performance, Financial and Non-financial incentives, Personality Determinants of personality, Type A and Type B personality, Values, Attitudes & Beliefs, Argyris's Maturity-Im maturity Continuum, Perception-Motivation and Perception, Meaning, Need of Perceptual process, Factors influencing Perceptual process, self-concept and self-esteem.

Unit 3: **6 hrs**

Group Dynamics and Stress Management: Group Dynamics-Team & Group difference, Group Effectiveness, Formal & Informal Group, Stages of Group Development, Group Decision Making, Inter group relation and Conflict, Stress Management-Stress and Behaviour, Sources of Stress, Consequences of Stress and Performance.

Unit 4 **6 hrs**

Leadership, Conflict Management and Power & Politics: Leadership-Introduction and characteristics of Leadership, Formal and Informal leadership, Theories of Leadership, Conflict Management-Nature of Conflict, Sources of Organizational Conflict, Modes of Conflict Resolution, Conflict Management, Power & Politics-Difference between Influence, Power &Authority, Sources of power, Organizational Politics, Machiavellian ism, Ethics of Power and Politics in Organizations.

Unit 5 **6 hrs**

Organization Development and Culture: Organizational Change, Resistance to change, Steps for planned change, Quality Work Life, Organization Development Objective and Interventions, Organization Climate and Organizational Effectiveness, Managing Organizational Culture.

Transaction Mode

Collaborative learning, Group Discussion, E team Teaching, Activities, Assessments, Collaborative teaching, Peer Teaching, Video Based Teaching, Quiz, Open talk, E team Teaching, Case analysis, Flipped Teaching

Suggested Readings

- *Uma Sekaran, Organisational Behaviour, Tata McGraw Hill*
- *John W Newstrom, Organisational Behaviour, Tata McGraw Hill*
- *Stephen P.Robbins, Timothy A. Judge, Niharika Vohra (18th ed.), Pearson Education, New Delhi*
- *L. M. Prasad, Organisational Behaviour, Sultan Chand & Sons*

SEMESTER-IV

Course Title: Dissertation Phase-II
Course Code:MME4650

L	T	P	Credits
-	-	-	20

Learning Outcomes: On successful completion of this course, the students will able to:

1. Create, analyze and critically evaluate different technical solutions.
2. Analyze the consciousness critically of the ethical aspects of research and development work.
3. Create analyze and evaluate different technical.
4. Explain the capability of critically and systematically integrate knowledge.

Course Content

The dissertation will normally contain:

1. A clear indication, at appropriate stages, of original and critically elements. The level of originality expected is likely to include the application of existing techniques to new environments, the use of original materials, the re-working of existing materials, and the Use of comparative approaches to the provision of information technology;
2. A discussion of its scope and aims, and its theoretical and professional significance, including discussion of the context in which the problem is seen as important;
3. An analysis of the topic within a critically review of the relevant literature;
4. An evaluation of methods used in the dissertation, their reliability, validity, and a comparison with alternative methods;
5. An account of the process of obtaining the data required for the dissertation and the results obtained;
6. An analysis of the results of the dissertation to include a discussion of their significance, their relationship to other research, and any methodological or theoretical implications;
7. The relationship of the findings to existing professional understanding and, where Appropriate, potential implementation difficulties. It is not intended to restrict students to a precisely defined format for the dissertation but it should follow the standard practices of dissertation writing. Although a written report will normally be expected, it should be accompanied by soft copy on CD.

Transaction Mode

Lecture, Seminar, e-Team Teaching, e-Tutoring, Dialogue, Peer Group Discussion, Mobile Teaching, Self-Learning, Collaborative Learning and Cooperative Learning

Course Title: Seminar
Course Code:MME4651

L	T	P	Credits
0	0	4	2

Total Hours: 60

Learning Outcomes: On successful completion of this course, the students will able to:

1. Communicate science in a 30-40-minute oral scientific presentation
2. Understand and critique scientific presentations

Course Content

Each student shall identify a topic of current relevance in his/her branch of engineering, get approval of faculty concerned, collect sufficient literature on the topic, study it thoroughly, prepare own report and present in the class

Course Title: Combustion Engineering
Course Code:MME4652

L	T	P	Credits
4	0	0	4

Total hours: 60

Learning Outcomes: On successful completion of this course, the students will able to

- To understand and analyze the combustion with emphasis on engineering applications

UNIT I
CHEMICAL REACTIONS
Fuels and combustion, Theoretical and actual combustion processes, Enthalpy of formation and enthalpy of combustion, First law analysis of Reacting systems, Adiabatic flame temperature, Entropy change of reacting systems, Second law analysis of reacting systems, problems

UNIT II
COMBUSTION OF GASEOUS AND VAPORIZED FUELS
Review of types of fuels, Types of flames, Energy balance and furnace efficiency, Burner type, Emissions from gas-fired furnaces, Emissions control, Chamber design, Detonation.

UNIT III
COMBUSTION OF LIQUID FUELS
Spray combustion in furnace, spray formation and droplet behaviour, Gas turbine operating parameters, combustor design, ignition delay, and detonation of liquid fuel sprays

UNIT IV
COMBUSTION OF SOLID FUELS
Drying of solid fuels, devolatilization of solid fuels, stoker-fired boilers, Refuse and biomass fired boilers, Pulverized coal-burning systems, Pulverized coal combustion, Emission from pulverized coal, Problems

UNIT V
FLUIDIZED BED COMBUSTION
Fluidization fundamentals, combustion in bubbling bed, atmospheric fluidized bed combustion systems, circulating fluidized beds, pressurized fluidized bed combustion, problems.

Suggested Readings

1. Yunus.A.Cengel- A textbook of Thermodynamics
2. Gary.L.Borman, Combustion Engineering-McGraw Hill international Edition,1998
3. Roger.A.Strehlow-Combustion fundamentals- McGraw Hill international Edition,1989.

Course Title: Vibration Analysis
Course Code:MME4653

L	T	P	Credits
4	0	0	4

Total hours: 60

Learning Outcomes: On successful completion of this course, the students will able to

- Determine natural frequency of undamped and damped single degree freedom systems
- Calculate natural frequencies of two degree freedom system
- Determine natural frequencies of multi degree freedom system
- Apply numerical methods to determine natural frequencies of multi degree freedom system
- Calculate critical speed of shaft and describe vibration measuring instruments

UNIT- I **12 hrs**

Lectures Single Degree of Freedom Systems: Undamped free vibration: Classical method, Energy method, equivalent systems, Damped free vibration- Viscous damping-underdamping, critical damping, overdamping; Coulomb damping, equivalent damping coefficient.

UNIT- II **12 hrs**

Lectures Forced vibrations of Single Degree Freedom Systems: Steady state forced vibration, sources of excitation, impressed harmonic force, resonance, impressed force due to rotating unbalance, base excitation, transmissibility and isolation, performance of different type of isolators, power absorbed by viscous damping.

UNIT- III **12 hrs**

Lectures Two degree Freedom Systems: Principal modes of vibration, two masses fixed on tightly stretched string, double pendulum, torsional system with damping, forced vibration with harmonic excitation, undamped dynamic vibration absorber, untuned viscous damper.

UNIT- IV **12 hrs**

Lectures Multi Degree Freedom Systems: Lagrangian method for formulation of equation of motion Rayleigh's method, Dunkerley's method, Stodola method, Rayleigh-Ritz method, Method of matrix iteration. .

UNIT- V **12 hrs**

Lectures Whirling of shafts: Critical speeds of shafts – Critical speed of a light shaft having a single disc – without damping and with damping. Critical speed

of a shaft having multiple discs – secondary critical speed. Vibration measurement and Applications: Piezoelectric transducers and linear variable differential transformer transducer; Vibration pickups: Vibrometer, Accelerometer, Vibration exciters- Mechanical exciters, impact hammer and electrodynamic shaker.

Suggested Readings

- G. K. Groover, Mechanical Vibrations, 8th Edition, Nem Chand & Bros, 2009
- L. Meirovich, Elements of Vibrations Analysis, 1st Edition, Tata McGraw Hill, 1986
- S. Graham Kelly, Mechanical Vibrations, 1st Edition, Tata McGraw Hill, 1996
- Singiresu S. Rao, Mechanical Vibrations, 6th Edition, Pearson Education, 2018

Course Title: Advanced Material Characterization Techniques
Course Code:MME4654

L	T	P	Credits
4	0	0	4

Total hours: 60

Learning Outcomes: On successful completion of this course, the students will able to

- Understand the mechanical behavior of ductile and brittle materials
- Analyze creep, fatigue and fracture mechanisms for various materials
- Develop fracture mechanism maps and analyze the reasons for failure of materials
- Select a characterization technique to evaluate the behavior of materials

Unit-1 **12 hrs**

Introduction: A brief review of elastic and plastic deformation, dislocations and their properties. Dislocations in FCC, BCC and HCP metals, interactions with point defects and other dislocations. Tensile behavior, evaluation of strength and ductility parameters, Effect of strain rate and temperature on tensile behavior, and Protevin Le-Chatelier effect.

Unit-2 **12 hrs**

Creep: Types and mechanisms of creep deformation, Creep under combined stresses, deformation mechanism maps, Super plasticity, environmental effects, remaining life assessment.

Unit-3 **12 hrs**

Fatigue: High and low cycle fatigue, process of fatigue fracture, effect of mean stress, Cyclic stress/strain response of materials, establishment of cyclic stress/ strain curve, transition fatigue life, Coffin-Manson relationship, Evaluation of parameters, characterizing resistance against high cycle and Low cycle fatigue, Creep fatigue interaction, environmental effects, thermochemical fatigue.

Unit-4 **12 hrs**

Fracture Mechanics: Brief review of the basic concepts of linear elastic and elastic-plastic fracture mechanics, stress intensity parameter, J- integral and crack tip opening displacement as fracture criteria, standard procedures for experimental determination of these parameters.

Unit-5 **12 hrs**

Failure analysis: Analyzing Fractures, Micro mechanisms of brittle and ductile fracture, fracture mechanism maps, fractography, Visual Examination & Management of Applied Failure Analysis, Manage Failure Analysis.

Materials characterization techniques: Optical microscopy techniques, Quantitative metallography, Scanning electron microscopy: Image formation methods in SEM. Applications.

Suggested Readings

- Mechanical Metallurgy, George E. Dieter, McGraw Hill, 2nd Edition, 2005.
- Introduction to Fracture Mechanics, Hellan K, McGraw Hill, 2002.
- Mechanical Behavior of Materials at Elevated Temperatures, J.E.Dorn, McGraw Hill, 2000.
- Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, 5th Edition, Wiley, 2012.
- Engineering Materials I: Introduction to Properties, Applications and Design, M.F Ashby and David R H Jones :,2010.
- Mechanical behaviour of Materials, Marc Andre Meyers and Krishna Kumar Chawla, 2009.

Course Title: Advanced Thermodynamics
Course Code:MME4655

L	T	P	Credits
4	0	0	4

Total hours: 60

Learning Outcomes: On successful completion of this course, the students will able to

1. Master core thermodynamics: Laws, entropy, exergy, real gases (Van der Waals, Joule-Thomson), and psychrometrics (air conditioning, cooling towers).
2. Analyze chemical reactions: Combustion, adiabatic flame temperature, equilibrium (Van't Hoff, Gibbs phase rule).
3. Evaluate power/refrigeration cycles: Rankine, Brayton, cogeneration, exergy analysis, and efficiency optimization.
4. Study irreversible processes: Onsager's relations, entropy production, thermoelectric effects.
5. Explore energy conversion: Fuel cells, MHD, thermoelectrics, and photovoltaics for sustainable systems.

UNIT-1 **15 hrs**

Review of Thermodynamic Laws and Corollaries

Transient Flow Analysis, Second law of thermodynamics, Entropy, Availability and unavailability, Irreversibility, Thermodynamic Potentials, Maxwell's relations, Specific Heat relations, Mayer's relation, Evaluation of Thermodynamic properties of working substance. P.V.T. surface, Equations of state, Real Gas behaviour, Vander Waal's equation, Generalised compressibility Factor, Energy properties of Real Gases, Vapour pressure, Clausius– Clapeyron Equation, Throttling, Joule–Thompson coefficient. Non-reactive Mixture of perfect Gases, Governing Laws, Evaluation of properties, Psychrometric properties and psychrometric chart, Air conditioning processes, Cooling Towers, Real Gas mixture.

UNIT 2 **12 hrs**

Chemical Reactions

Combustion, Combustion Reactions, Enthalpy of Formation, Entropy of Formation, Reference Levels for Tables, Energy of formation, Heat of Reaction, Adiabatic flame Temperature- General Problems, Enthalpies, Equilibrium. Chemical Equilibrium of Ideal Gases, Effects of Non-reacting Gases Equilibrium in Multiple Reactions. The VantHoff's Equation. The chemical potential and phase Equilibrium, the Gibbs phase Rule.

UNIT 3 **10 hrs**

Power Cycles Review, Binary vapour cycle, co-generation and Combined cycles, Second law analysis of cycles, Refrigeration cycles.

UNIT 4 **12 hrs**

Thermodynamics of Irreversible Processes

Introduction, phenomenological laws, Onsager Reciprocity Relation, Applicability of the phenomenological Relations, Heat Flux and Entropy Production, Thermodynamic phenomenon, Thermoelectric circuits.

UNIT 5 **11 hrs**

Direct Energy Conversion

Introduction, Fuel Cells, Thermo-electric energy, Thermo-ionic power generation - Thermodynamic devices, Magneto Hydrodynamic Generators, Photo-voltaic cells.

Suggested Readings

1. Fundamentals of Thermodynamics, Sonntag, Borgnakke and Van Wylen, Wiley, 6th Edition
2. Thermo dynamics, Doolittle, Messe
3. Basic and Applied Thermodynamics, P.K. Nag, TMH
4. Thermodynamics, Moran and Shapario
5. Thermodynamics, Holman, McGraw Hill
6. Irreversible Thermodynamics, HR De Groff.
7. Engineering Thermodynamics, PL.Dhar

Course Title: Design of Experiments
Course Code:MME4656

L	T	P	Credits
4	0	0	4

Hours- 60

Learning Outcomes: On successful completion of this course, the students will able to

- Decide whether to run a DOE to solve a problem or optimize a system
- Set-Up a Full Factorial DOE Test Matrix, in both Randomized and Blocked forms
- Analyze and Interpret Full Factorial DOE Results using ANOVA, (when relevant) Regression, and Graphical methods
- Set-Up a Fractional (Partial) Factorial DOE, using the Confounding Principle
- Analyze and Interpret the results of a Fractional Factorial DOE
- Recognize the main principles and benefits of Robust Design DOE
- Decide when a Response Surface DOE should be run
- Select the appropriate Response Surface Design (either Plackett-Burman, Box-Behnken, Central Composite, or D-Optimal)
- Interpret Response Surface Outputs
- Utilize the MiniTab® Software tool to analyze data

Design of Experiments (DOE) is a methodology that can be effective for general problem-solving, as well as for improving or optimizing product design and manufacturing processes. Specific applications of DOE include identifying proper design dimensions and tolerances, achieving robust designs, generating predictive math models that describe physical system behaviour, and determining ideal manufacturing settings. This course utilizes hands-on activities to help you learn the criteria for running a DOE, the requirements and pre-work necessary prior to DOE execution, and how to select the appropriate designed experiment type to run. You will experience setting up, running, and analyzing the results of simple-to-intermediate complexity, Full Factorial, Partial Factorial, and Response Surface experiments utilizing manual methods as well as a hands-on computer tool that facilitates experimental design and data analysis. You will also receive an overview of Robust DOE, including the Taguchi DOE Method.

Course Title: Jig Fixture and Die Development
Course Code:MME4657

L	T	P	Credits
4	0	0	4

Hours - 60

Learning Outcomes: On successful completion of this course, the students will able to

1. Design jigs, fixtures & dies with tolerances.
2. Automate clamping & loading using pneumatic/hydraulic systems.
3. Build specialized fixtures for drilling/milling/assembly.
4. Engineer progressive, bending & drawing dies.
5. Optimize production with gauging & modular design.

UNIT I **15 hrs**

Jigs and Fixtures: Elements of jigs and fixtures, costs calculations. Locating element, clamping elements, procedure in designing. Jig and fixtures: Fits and tolerances analysis.

UNIT-II **15 hrs**

Non-Standard clamping devices, centerlizers, equalizers, actuators (Pneumatic, hydraulic electric and electronic.) Automatic loading and unloading devices. Types of Frunions: Single, double and multi-axis and indexers.

UNIT III **15 hrs**

Transfer line jigs & fixtures for the operation of Multi-drilling, boring, milling and grinding. Assembly line fixtures. Universal Jigs and Fixtures.

UNIT IV **15 hrs**

Transfer-devices, transfer machine, modulation-design concept, in process gauging. Design of Dies: Elements of Dies and Punch. Types and design procedure, progressive dies, drawing die, bending die etc. Analysis

Suggested Readings

1. Jigs and Fixtures Design Haughton
2. Jigs and Fixtures Design Hardy
3. Jigs and Fixtures Parson.