COURSE STRUCTURE AND SYLLABUS
FOR M.TECH PROGRAMME IN
MAINTENANCE ENGINEERING AND TRIBOLOGY

Semester – I

Sl. No.	Course No.	Subject	L	T	P	Cr. hrs.
1.	AMC 51101	Advanced Numerical Methods & Applied Statistics	4	0	0	8
2.	MCC 51101	Fundamentals of Tribology	3	0	0	6
3.	MCC 51102	Mechanical Vibrations	3	0	0	6
4.	MMC 51103	Diagnostic maintenance and condition monitoring	3	0	0	6
5.		**Elective(Any one)**	**3**	**0**	**0**	**6**
a.	MCC 51110	Lubrication and Bearing Design				
b.	MCE 51102	Finite Element Method				
c.	MCE 51103	Modeling and Simulation of Dynamical Systems				
d.	ACE 51137	Corrosion and Corrosion protection				
Practical and/or others						
6.	AMC 51201	Advanced Numerical Methods & Applied Statistics	0	0	2	2
8.	MCC 51201	Tribology Laboratory	0	0	3	3
9.	MCC 51601	Industrial/Laboratory visit	0	0	0	(2)
10.	MCC 51401	Seminar	0	0	2	2
		Total	16	0	7	39+(2)

Semester – II

Sl. No.	Course No.	Subject	L	T	P	Cr. Hrs.
1.	MCC 52101	Design of Tribological Components	3	0	0	6
2.	MSC 52105	Operations Research-II	3	1	0	7
3.	MCC 52102	Reliability, Availability, Maintainability and Safety (RAMS)	3	1	0	7
4.	ACC 52136	Chemistry of Lubricants and Additives	3	1	0	7
5.		**Elective (any one)**	**3**	**0**	**0**	**6**
a.	MCE 52101	Maintenance Engineering				
b.	MCE 52102	Composite Materials				
c.	MCC 52103	Automation and Control				
Practicals and others						
6.	ACC 52266	Chemistry of Lubricants and Additives Practical	0	0	2	2
7.	MCC 52501	Comprehensive Viva-voce	0	0	0	(2)
8.	MCC 52401	Seminar	0	0	2	2
	-	Industrial Training (to be credited in IIIrd Sem.)	-	-	-	-
		Total	15	3	4	37+(2)

III SEMESTER

Course No.	Subject	L-T-P	Credit Hours
MCC 53903	Industrial Training (taken in II semester)	0 – 0 – 0	4
MCC 53401	Seminar / Term Paper	0 – 0 – 2	2
MCC 53905	Interim Dissertation & Viva Voce	0 – 0 – 0	20
MCC 53002	Teaching Assignment Evaluation/ Laboratory Development Work etc.	0 – 0 – 0	10
Total		0 – 0 – 0	36

IV SEMESTER

Course No.	Subject	L-T-P	Credit Hours
MCC 54902	Dissertation &Viva Voce	0 – 0 – 0	25
MCC 54002	Teaching Assignment Evaluation/ Laboratory Development Work etc.	0 – 0 – 0	10
Total		0 – 0 – 0	35

SEMESTER I

AMC511 Advanced Numerical Methods & Applied Statistics 4 0 0

Section A: Adv. Num. Methods – Review of solution of system of linear simultaneous equation. Solution of tridiagonal system, III conditioned system and iterative method to improve accuracy of an ill conditioned system. Evaluation of double and triple integrals by numerical methods and its application, solution of non-linear simultaneous equations, numerical solutions of integral equations, advanced method of interpolation, spline interpolation, numerical solution of simultaneous first order ordinary differential equations and higher order O.D.E. Initial and boundary value problems; Numerical solution of partial differential equations; Laplace and Poisson equation; heat conductive and wave equations; Writing computer program in the above methods.

Section B: Applied Statistics – Review of binomial, negative binomial, Poisson, normal and log normal distribution. Test of significance of mean, variance, correlation and regression coefficients; χ^2 test of goodness of fit; attributes and contingency table; F tests, tests of proportions, tests of significance under large sample approximation. Non-parametric tests: Wald-Wolfowitz run tests, tests of randomness, median tests, sign tests, Mann-Whitney Wilcoxon U-tests. Time series analysis, introduction to reliability and life testing experiments in engineering problems. One way and two-way analysis of variance, Completely Randomized Design (CRD), Randomized block Design (RBD), Latin Square Design (LSD).

MCC 51101 Fundamentals of Tribology **3 0 0**

Introduction: Friction, wear and lubrication.
Engineering surfaces, nature of surface and surface measurements.
Friction: Origin of Friction; Friction theories; Measurement methods.
Wear: Types of wear - adhesive, abrasive, fatigue, corrosive etc.; Testing methods; Wear debris analysis; Wear reduction methods.
Lubrication: Basic equations of the theory of lubrication, calculation of oil flow rate; Methods of lubrication; Types of industrial lubricants and their standard grades; Boundary, hydrostatic and hydrodynamic lubrication.

References:

1. Principles of Tribology J. Halling
2. Engineering Tribology Prasanth Sahoo
3. Friction & Wear B. Pugh
4. Fundamentals of Tribology Basu, Sengupta, Ahjua
5. Friction, Wear, Lubrication K. C Ludema

MCC 51105 Mechanical Vibration 3 – 0 – 0

Free and forced vibration of single degree of freedom system with and without damping concept of phase plane. Response of single degree of freedom system to impulse, periodic and non-periodic excitation. Multi degree of freedom free, forced, undamped and damped vibration; Multi degree of freedom system – exact analysis and numerical methods; Vibration in continuous systems; Vibration isolation, absorption and measurements in industrial machines.
References:

1. Vibration fundamentals and practices – Clarence W.de Silva; CRC press.
2. Vibration and noise for engineers – Kewal Pujara; Dhanpat Rai and Sons
3. Theory of vibrations with applications – William T Thomson; CBC Publishers and distributors
4. Vibrations, Waves and Acoustics – D Chattopadhyay and P C Rakshit; Books and Allied(P) Ltd.
5. Elements of Vibration analysis – Leonard Meirovitch; MGH Intl. Editions
6. Textbook of Mechanical Vibration – Rao, Dukhipati, Srinivas; PHI Pvt. Ltd.

MMC 51102 Diagnostic Maintenance and Condition Monitoring 3-0-0

Introduction: Maintenance function; Maintenance cycle; Planning, Execution, Recording and Evaluation.
Types of maintenance; Preventive and corrective Maintenance; Condition Based Maintenance and Condition Monitoring; Cost effectiveness.
Different condition monitoring Techniques; Visual, performance, fluid and vibration monitoring.
Fluid condition and particle monitoring; Fluid degradation and its identification methods; Chemical tests, infrared spectroscopy, calorimetry.
Wear debris analysis; SOAP, Ferrography and other spectrometric analysis techniques for wear rate evaluation and interpretation.
Vibration monitoring methods; Vibration data collection; Techniques; Instruments; Transducers; Commonly witnessed machinery faults diagnosed by vibration analysis.

References:

1. Collacot R.A.- Mechanical fault diagnosis and condition monitoring
2. Hunt, T.M., (1993), Handbook of wear debris analysis and particle detection in liquids, Elsevier applied science, London and New York
3. Rao, B. (1996), Handbook of condition monitoring, Elsevier advanced technology, Oxford.
4. A Davis – Handbook of condition monitoring.
5. P Girdhar – Machinery vibration analysis and predictive maintenance
6. R G Eisenmann et-al – Machinery malfunction diagnosis and correction
7. John S Mitchell – Machinery analysis and monitoring

MCE 51105 Lubrication and Bearing Design 3 0 0

Basic principles of lubrication, lubrication theories; Hydrostatic, boundary, hydrodynamic and elasto-hydrodynamic lubrication. Generalized Reynolds equation, flow and shear stress. Mechanism of hydrodynamic instability. Dynamic characteristics of hydrodynamic journal bearings.
Plain bearing lubrication and performance. Design, application and selection of various types of bearings – sliding and rolling element bearings. Concept of air and magnetic bearings.

References:

1. Introduction to tribology of bearings B.C.Majumdar
2. Principles of Tribology J. Halling
3. Engineering Tribology Prasanth Sahoo
4. Friction & Wear B. Pugh
5. Fundamentals of Tribology Basu, Sengupta, Ahjua

MCE 51104 Finite Element Method 3 — 0 — 0

Principles of variation calculus.
Methods of Finite element analysis: stiffness method, potential energy and Rayleigh-Ritz method, Galerkin FE formulation, element formulation, and coordinate transformation, isoparametric formulation.
Applications: problems of structural mechanics and solid mechanics. Plane stress & plane stress problems, 3-D problems. Torsion, bending of plates and shells. FE formulations for vibrations, heat transfer and fluid flow problems.
Associated flowcharts and computer programming. Non-linear bending of straight beams and elastic plates

References:

1. Introduction to Finite Elements in Engineering, T. R. Chandrupatla & A. D. Belegundu, 2nd Ed., PHI, 2001.
2. An Introduction to the Finite Element Method, Reddy, J. N., 2005.
3. The Finite Element Method, O. C. Zienkiewicz, 3rd Ed., McGraw-Hill, 1997.
4. The Finite Element Method in Engineering, S. S. Rao, 2nd Ed., Elmsford, Pergamon, 1989.
5. Introduction to the Finite Element Method: A Numerical Method for Engineering Analysis, Desai, C. S. and Abel, J. F., 1972

MCE 51109 Modeling and Simulation of Dynamical Systems 3 – 0 – 0

Elements of analytical mechanics; classification of constrains; Lagrange's first equation; Lagrange's second equation; Hamilton's equations; Nonholonomic mechanical system dynamics, Dynamics of rigid bodies, modeling in noninertial coordinates, modeling of Physical systems: Electrical systems, mechanical systems, structural members, thermal systems, and hydraulic systems. Advanced topics in bond graph modeling: Elements of bond graphs, the notion of causality, generation of system equations. Bond graphs of dynamic systems. Introduction to various system simulation software.

References:

1. Karnopp, D.C., Margolis, D.C. and Rosenberg, R. System dynamics: A unified approach, 1990, John Wiley, New York.
2. Mukherjee, A., Karmakar, R. and Samantaray, A.K. Bond Graph in Modeling, Simulation and Fault Identification, 2006, I. K. International: New Delhi, India, ISBN 81-88237-96-5.
3. Borutzky W. Bond graphs - A methodology for modelling multidisciplinary dynamic systems, 2004, SCS Publishing House, Erlangen, San Diego.
4. Samantaray, A.K. and Ould Bouamama, B. Model-based process supervision: A bond graph approach, 2008, Springer Verlag, London
5. Borutzky, W. (Ed.) Bond Graph Modelling of Engineering Systems: Theory, Applications and Software Support, 2011, Springer Verlag, ISBN 978-1-4419-9367-0

ACE 51137 Corrosion and Corrosion Protection 3 0 0

Basic concepts of corrosion: Importance, corrosion theories, kinetics and mechanism of corrosion processes. Metallurgical factors and forms of corrosion: Crystal structure and metallic bond, crystal defects, effects of casting procedures, heat treatment, mechanical working and composition, corrosion resistant alloys. Different forms of corrosion and their control methods. Environmental aspects: Atmospheric corrosion, underground corrosion, biological corrosion – mechanisms and control measures. Corrosion testing and monitoring: Laboratory corrosion tests, corrosion monitoring methods. Chemical and electro-chemical removal of corrosion products. Cathodic and anodic protection: Principles, applications, advantages and disadvantages. Chemical methods of corrosion control: Use of inhibitors and coatings. Corrosion in industries and specific corrosion control methods.

Practical

AMC 51201 Advance Numerical Methods and Applied Statistics Lab 0-0-2

Part-1 (Advance Numerical Methods)

Solution of tri diagonal systems. Solution of simultaneous non-linear equations by Iteration and Newton Raphson Method. Evaluation of double integrals. Solution of initial value problems, Solution of B.V. P. by finite difference method. Solution of Laplace and Poisson equations, Solution of heat conduction Equation, Solution of wave equation.

Part-2 (Applied Statistics)
Practical based on: Tests of significance for one and two-population case, tests of regression and correlation coefficients, tests of proportion, non-parametric tests, time series analysis, reliability & life testing experiments, Completely Randomized Design, Randomized Block Design and Latin Square Design.

MCC 51201 Tribology Laboratory 0-0-3

1. Study of wear characteristics of machine components
2. Study of surface characterization of wear components
3. Variation of viscosity with temperature of lubricants
4. Pressure variation of hydrodynamic lubrication
5. Assessment of surface integrity of machine components

SEMESTER II

MCC 52101 Tribological Materials 3 -0- 0

Introduction to tribological processes and tribologically relevant properties of materials, friction materials and their application. Antifriction/conventional bearing materials, wear resistant materials. An overview of engineering materials having potential for tribological application. Characterization of Ferrous and non-Ferrous materials for tribological requirements/applications. Surface treatment techniques with applications such as carburising, nitriding, induction hardening, hard facing and laser surface treatments. Surface coating techniques such as electrochemical depositions, anodizing, thermal spraying, Chemical vapour deposition. Materials for specific applications e.g. seals, hydraulic components and high temperature & low temperature (freezing conditions) applications.
Lubricants and lubrication types: types and properties, additives and their role; Grease, solid lubricants. Standards, evaluation, testing and selection of lubricants. Hydrodynamic Lubrication - Elasto hydrodynamic lubrication, Boundary Lubrication - Solid Lubrication Hydrostatic Lubrication Salvaging and re-use of lubricants. Critical environmental problems related to use of lubricants and possible control measures.
Evolution and characteristics of Nano-materials for tribological applications.

MCC 52103 Design of Tribological Components 3-1-0

Introduction-Tribological consideration in design.
Tribological Elements : Sliding Bearing, Journal Bearings, Rolling contact bearing, Piston, piston ring liner etc.
Types of wear and their Mechanism: Wear in lubricated contact – Film lubrication
Elements of contact Mechanics: Thermal effects in surface contact, Contact between rough surface.
Friction, Lubrication and wear in Clutches, Brakes, Pneumatic Tyres, Mechanical Seals, drives etc.
Sliding Bearings: Thrust bearings, Journal Bearings, – Application, selection, modern developments.
Rolling Contact Bearings: Bearing materials, Trouble-shooting and Bearing Problems.

References –
Tribology in machine design -- By --T. A. Stolarski
Tribology & design - edited by M. Hadfield, C. A. Brebbia, J. Seabra
Tribological Design of Machine Elements by D. Dowson , C.M. Taylor, M. Godet, D. Berthe

MSC 52105 Operations Research-II (3 - 1 - 0)

Review of linear programming technique and its solution methodology; Integer programming and its application in managerial decision making, solution methodologies, zero-one programming; Dynamic programming; principle of optimality, concepts of state and stage, solution of discrete and continuous dynamic programming problems; Introduction of Markov decision process; Queuing theory: definitions and classification; Applications; Discrete event simulation and its applications; Concept of multi criteria decision making; Stochastic decision making models: decision tree, introduction to stochastic programming model; soft optimization methods: Genetic Algorithm, Simulation annealing, Neural network and heuristic programming methods.

ACC 52136 Chemistry for Lubricants and Additives 3 1 0

Physical and mechanical properties, performance and production of solid, semi-solid, liquid and synthetic lubricants. Lubricant formulation and its importance in effective machinery lubrication. Chemistry of Lubricating oils, Hydraulic fluids, Greases and Additives (used to enhance lubricant performance). Chemistry of lube oil oxidation, effect of oxidation on lubricant properties. Indications of oil oxidation. Machine fault detection through lubricant analysis. Tools used in analysis of lubricants.

MCE 52104 Maintenance Engineering 3 0 0

Maintenance – Key to reliability & productivity. Basic elements of maintenance system – inspection, planning & scheduling, job execution, record keeping, data analysis, learning & improvement.
Basic definitions, preventive, operating and shutdown maintenance; Condition based maintenance and condition monitoring. Application of preventive maintenance for system of equipment.
Vibration and signature analysis; causes; remedy in rotating machinery. Fluid analysis for condition monitoring, various methods of fluid analysis.
Non-destructive testing, principle methods such as dye-penetrant, magnetic particle testing and ultrasonic tests.
Lubrication: Introduction to lubrication engineering, types, classification of lubricants with their properties and characteristics. Bearing lubrication technique for minimization of friction and wear.
Science of friction and wear; Different types of wear, such as abrasive, corrosive, seizure, scoring, scuffing, pitting, spalling, adhesive, etc. and techniques for minimization of wear.
Data collection and analysis, Introduction to computer-aided maintenance management system.

References:

1. Industrial Maintenance – H.P.Garg
2. Ind. Maint. Management – S.K.Srivastava

MCE 52102 Composite Materials 3 – 0 – 0

Introduction to composites: basic concepts, structural applications, classification, strength and stiffness advantages, manufacturing aspects of composites.
Micro-mechanics : mechanics of materials method, bounding methods, semiemperical methods, longitudinal and transverse elastic properties, inplane shear modulus, stress – strain relations for general anisotropic, specially orthotropic and transversely isotropic materials, 2d

transformation of stress – strain, elastic parameters, engineering constants, 3d transformation of stress – strain, and elastic parameters.

Macro-mechanics: strength analysis of unidirectional lamina under various loading conditions, failure theories, computational procedure for determination of lamina strength – tsai – wu criterion.

Elastic behavior of multidirectional laminates – symmetric and asymmetric laminates, computational procedure for determination of engineering elastic properties, carpet plots for multidirectional laminates.

Stress and failure analysis of multidirectional laminates, hygrothermal effects, experimental methods for characterization and testing of composite materials. design of laminates.

References:

1. Mechanics of composite materials, Rr. M. Jones, 2nd edn. Taylor & francis, 1999.
2. Engineering mechanics of composite materials, I. M. Daniel & O. Ishai, 2nd edn., oxford university press, 2006.
3. Principles of composite material mechanics, R. F. Gibson, 2nd edn. CRC Press, 2007.

MCC 52103 Reliability, Availability, Maintainability and Safety (RAMS) 3 – 1 - 0

Introduction: Types of System; Series system; Parallel system; Series-Parallel System; Redundancy in Systems. Difference between System and Component: System and Component Reliability; Markov Model.

Definition and concept (Reliability, Maintainability, Availability, Safety); MTBF, MTTF, MTTR concept, Bathtub curve concept. Failure Rate and Degradation; Stochastic and Non-Stochastic Processes; Repairable and Non-Repairable Systems; Reliability data and censoring Approaches; Probability concept overview.

Probability Distributions and Distribution Models: Discrete and Continuous Distribution; ; Normal Distribution; Exponential Distribution; Weibull Distribution; ; Gamma Distribution; Lognormal Distribution; Goodness of Fit tests; Reliability Modelling and Model Selection.

Monte Carlo Simulation; Risk analysis and Risk Matrix; Quantitative and Qualitative Analysis; RCM concept; FTA and ETA analysis technique; FMECA, PHA and HAZOP analysis; Reliability Management and Product Life Cycle (General Overview); Industrial Case Studies

References:

1. Abernethy, R.B. (2003). *The New Weibull Handbook,* 4th ed., ISBN 0-9653062-1-6.
2. Ascher, H.E. and Feingold, H. (1984). *Repairable Systems Reliability- Modelling, Inference, Misconceptions and their Causes.* Marcel Dekker Inc., New York, ISBN 0-8247-7276-8.
3. Barlow, R.E. and Proschan, F. (1965). *Mathematical Theory of Reliability.* John Wiley, New York.
4. Billinton, R. and Allan, R.N. (1983). *Reliability Evaluation of Engineering Systems: Concepts and Techniques.* Pitman Books Limited, Boston.
5. Dhillon, B.S. (2002). *Engineering Maintenance: A Modern Approach.* CRC Press, Boca Raton, Florida.
6. IEV 191-07-01 (2001). *Dependability and Quality of Service/Maintenance.* International Electrotechnical Vocabulary (IEV). Online Database.
7. Available Online: http://std.iec.ch/iec60050;
8. Jardine, A.K.S. and Tsang, A.H.C. (2006). *Maintenance, Replacement, and Reliability: Theory and Applications.* CRC Press, Taylor & Francis Group, ISBN 0-8493-3966-0.
9. O'Connor, P.D.T. (1991). *Practical Reliability Engineering*. John Wiley, Chichester, UK.
10. Rigdon, S.E. and Basu, A.P. (2000). *Statistical Methods for the Reliability of Repairable Systems.* John Wiley & Sons, New York.
11. Ross, S.M. (1970). *Applied Probability Models with Optimization Applications.* Holden Day, San Francisco.
12. Blischke, W.R. and Murthy, D.N.P. (2003). *Case Studies in Reliability and Maintenance,* John Wiley & Sons, USA.

13. Nowlan, F.S. and Heap, H.F. (1978), *Reliability Centered Maintenance,* Springfield, Va.: National Technical Information Service (NTIS), US Department of Commerce.

14. **Software Recommended for Reliability Analysis and Modelling:** Reliasoft Corporation (2003). Weibull++ software, web: www.weibull.com

MCC 52103 **AUTOMATION AND CONTROL** **3-0-0**

Introduction; Mathematical models of physical system; Feedback characteristics of control systems; Control systems and components; Time response analysis, design specifications and performance indices; Concepts of stability and algebraic criteria; Root locus technique; Frequency response analysis; Stability in frequency domain; State variable analysis and design; Controllability and Observability; Optimal control; Adaptive control; Open loop control and closed loop control, Positive and negative feedback, Stepper motor and servo motor, PTP and Continuous control, PID Control Introduction to digital control systems; 8085/8080A Microprocessor architecture and programming.

References:

1. Automatic Control Engineering by F.H.Raven, 5th ed., McGrawHill International.
2. Modern Control Engineering by K.Ogata, Prentice Hall.
3. Digital Control Systems by B.C.Kuo, Prentice Hall.
4. Microprocessor architecture, programming, and applications with the 8085/8080A by Ramesh S. Gaonkar, Wiley Eastern Ltd.

Fundamentals of Linear State Space Systems by John S. Bay, WCB/McGraw-Hill

Practicals:

ACC 52266 **Chemistry for Lubricants and Additives Practical 0 0 2**

Determination of Viscosity, TAN, TBN and Flash point of lubricants. Analysis of lubricants based on FTIR and DSC.