

COURSE OF STUDY

FOR

M.TECH

(INDUSTRIAL TRIBOLOGY AND MAINTENANCE MANAGEMENT)

IN

MECHANICAL ENGINEERING

AT

N.I.T SRINAGAR

J&K-190006

FIRST SEMESTER

Course No.	Subject	C	L	T	P
TMM- 101	Friction, Wear and Lubrication	4	3	0	2
TMM- 102	Maintenance and Reliability	3	3	0	0
TMM- 103	Tribo-materials	3	3	0	0
TMM- 104	Elective-I	3	3	0	0
MSD- 104	Design Optimization	4	3	0	2
Total Credits & LTP		17	15	4	4

SECOND SEMESTER

Course No.	Subject	C	L	T	P
TMM- 201	Condition Monitoring	4	3	0	2
TMM- 202	Lubricant selection and applications	3	3	0	0
TMM- 203	Seminar and industrial training	3	0	0	6
TMM- 204	Elective-II	3	3	0	0
MSD 204	Wear Analysis & Control	3	3	0	0
Total Credits & LTP		16	11	0	8

ELECTIVE –I		ELECTIVE-II	
TMM 10*	Noise Monitoring and Control	TMM 20*	Design for Maintenance
TMM 10*	Human Factor Engineering	TMM 20*	Value Engineering
		TMM 20*	Advanced Manufacturing Systems

THIRD SEMESTER

Course No.	Subject	Credits	L	T	P
TMM- 301	Computer Applications in Maintenance	3	2	0	2
MSD 301	Design Of Tribosystems	4	3	0	2
ITMM-303	Dissertation	6	0	0	16
Total Credits		13	5	0	20

FOURTH SEMESTER

Course No.	Subject	Credits	L	T	P
TMM- 401	Dissertation	16	0	0	32
Total Credits		16	0	0	32

Course No: TMM-101 FRICTION WEAR AND LUBRICATION C L P (4 3 2)

Course topics:

UNIT I

Introduction to Tribology and its historical background, Factors influencing Tribological phenomena Engineering surfaces - Surface characterization, Computation of surface parameters, Surface measurement techniques, Apparent and real area of contact, Contact of engineering surfaces - Hertzian and non-hertzian contact, contact pressure and deformation in non-conformal contacts

UNIT II

Genesis of friction, friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction, Stick slip friction behavior, frictional heating and temperature rise, Friction measurement techniques, Friction in tribo-systems, Frictional Devices in mechanical systems.

UNIT III

Wear and wear types, Mechanism of wear-adhesive, abrasive, corrosive, erosion, fatigue, fretting, etc., Wear of metals and non-metals, Wear models- asperity contact, constant and variable wear rate, geometrical influence in wear models, wear damage, Wear in various mechanical components, wear controlling techniques, Introduction to lubrication regimes - Boundary Lubrication, Hydrodynamic Lubrication, Elastohydrodynamic Lubrication.

Text books:

1. Czichos, H., "A system approach to science and Technology of Friction, Lubrication and Wear" Volume I, Tribology series, Elsevier Publications, 1978.
2. Ludema, K.C., "Friction, wear, Lubrication", CRC Press, NY., 1996.

Reference books:

1. Peterson M.B., Winner W.O, "Wear control Handbook" sponsored by The Research Committee on Lubrication, 1980.
2. Cameron A., "The principles of Lubrication", Longman, London, 2000.

Course No: TMM-102 MAINTENANCE AND RELIABILITY C L P (33 0)

Course topics:

UNIT I

Evolution of maintenance, objective of maintenance, maintenance policies and philosophies, maintenance concept, maintenance management & terotechnology, relationship with functional areas, importance of maintenance, elements of good maintenance, Economics of maintenance, training and safety aspects in maintenance.

Classification of maintenance programs, corrective preventive and predictive maintenance, comparison of maintenance programs, preventive maintenance- concepts, functions, benefits, limitations.

UNIT II

Spare and Inventory planning, Manpower planning, Maintenance performance and Maintenance Auditing. Reliability centered maintenance (RCM) RCM logic, benefits of RCM, introduction to Total productive maintenance (TPM), Objectives, key supporting elements of TPM, methodology, evaluation and benefits.

UNIT III

Introduction to Reliability systems - series, parallel and hybrid systems, Techniques for improvement of operational reliability, Reliability calculations, and availability of machines and production systems, maintainability criteria, checklist to assess the maintainability of a system, maintainability programs, objectives, key issues in availability improvements program, fault diagnosis, Pareto principle Ishikawa diagram, Failure distribution-Constant failure rate, Weibull analysis etc.

Text books:

1. Duffuaa, S. O. and Raouf, A., Planning and control of maintenance Systems: Modeling and Analysis; John Wiley Inc., 1999.

Reference books:

1. Higgin L.R., "Maintenance Planning and Control", McGraw- Hill Book Co., 1990.
2. Kelly Anthony, " Maintenance Planning and Control", East West Press Private Ltd, New Delhi, 1991.
3. Blanchard B.S. and Lowey E.E., " Maintainability principle and practices", McGraw Hill Book.
4. Niebel Benjamin W. Marcel Dekher, "Engineering Maintenance Management" 1994.

Course No: TMM-103

TRIBO-MATERIALS

CL P (3 3 0)

Course topics:

UNIT I

Introduction to tribological processes and tribological relevant properties of material. An overview of engineer materials having potential for tribological application. Selection of materials for tribological applications at design stage.

UNIT II

Characterization and evaluation of Ferrous material for tribological requirements/application, Selection of ferrous material for rolling elements bearings, gears, crank shafts, piston rings, cylinder liners, etc. Non-ferrous materials and their applications such as e- sliding bearing, piston rings, cylinder liners, etc., materials for dry friction materials. Composite materials (PM, CMC and MMC) for tribological application.

UNIT III

Surface treatment techniques with applications such as carburizing, nitriding, induction hardening, hard facing, laser surface treatments, etc. Surface coating techniques such as electrochemical deposition, anodizing, thermal spraying, Chemical Vapour Deposition (CVD), Physical Vapour Deposition (PVD), etc. and their applications.

Text books:

1. Ashby, M.F., "Materials selection in mechanical design", 4th Edition, Butterworth Heinemann, London, 2010.
2. Glaeser, W. A., "Tribology series - Vol. 20," *Elsevier Publications*, 1992.
3. Neale, M.J., "The Tribology Hand Book," *Butterworth Heinemann, London*, 1995.

Reference books:

1. Peterson, M. B., Winer, W.O., "Wear Control Handbook," *ASME, NY* 1980.

Course No: MSD 104

DESIGN OPTIMIZATION

C L P (4 3 2)

Course topics:

UNIT I

Motivating examples of calculus of variations, Fundamental lemmas of calculus of variation, Euler-Lagrange (E-L) equations, Applications of E-L equation, Extensions of E-L equation to multiple derivatives, independent variables, multiple state variables. Isoperimetric problems-global and local (finite subsidiary) constraints, Applications of optimizing functional subject to constraints, Applications in mechanics: strong and weak forms of governing equations, Variable end conditions--transversality conditions. Size optimization of a bar for maximum stiffness.

UNIT II

Optimization with side constraints (variable bounds), Worst load scenario for an axially loaded stiffest bar, Min-max type problem with stress constraints, Beam problems for stiffness and strength, Optimization of a beam for given deflection, Variational formulations for the eigenvalue problems: strings, bars, beams, and other elastic structures, Optimum design of a column, Variable-thickness optimization of plates, sufficient conditions for E-L optimum.

UNIT III

Finite dimensional optimization- A summary and highlights of Numerical optimization techniques using the optimization tool-box in MATLAB, Gear design optimization.

Text Book:

1. Robert Weinstock, "Calculus of Variations with Applications to Physics and Engineering", Dover publications, 1974.

Reference Books:

1. Gupta, A.S., "Calculus of Variations with Applications", Prentice-Hall of India Pvt. Ltd., New Delhi, 2008.

2. Gelfand, I.M., Fomin, S.V., "Calculus of Variations", Dover publications, 2000.

Course No: TMM 10* NOISE MONITORING AND CONTROL CL P (3 3 0)

Course topics:

UNIT I

Introduction to sound and noise, Effects of noise, physics of sound, Sound intensity, frequency of sound, relationship of sound pressure, sound power and sound intensity. Sound control principle; Isolation, Absorption; Vibration isolation, vibration damping, material selection, equipment specifications, noise control regulation

UNIT II

Microphones, sound fields, frequency weighting, sound level meters; frequency response, reighting, calibration, sampling procedure, Determination of equivalent sound level, noise dosimeters, frequency analyzers, related vibration measurements. Types of fans, noise source, modifications, isolators, mufflers, location, balancing and maintenance.

UNIT III

Basic mechanism of gear noise generation, Principle sources of various excitation and espouse harmonic sets. Types of bearings and sources of noise, noise control; selection of bearings to reduce noise. Introduction, Passive and Active control approaches, Noise control in enclosed spaces, Sound propagation in ducts, Active control; digital system and controller output.

Text books:

1. L.H.,Bell, C.BeU, "Industrial Noise Control: Fundamentals and Applications", second edition CRC Press 2nd Edition NY 1993
2. S.Skaistis, "Noise Control of Hydraulic Machinery," Marcel Dekker.NY 3rd Edition 1988
3. C.Hansen, H. Colin "Noise Control: From Conceptto Application", CRC Press.NY 1st edition 2005

Reference books:

1. L Nicholas P. Cheremisinoff, William, "Noise Control in Industry: A practical guide,"
2. S.D.,Snyder, "Active Noise Control Primer", Springer. 1 51 edition 2005
3. D. A. Bies.C, H. Hansen, "Engineering Noise Control: Theoryand Practice". Taylor &Francis NY 2009

Course No: TMM-201 CONDITION MONITORING

CL P (4 3 2)

Course topics:

UNIT I

Introduction to condition based Maintenance (CBM), condition monitoring (CM) and the integrity of industrial systems, CM & Diagnostic Engineering management. Economic justification and benefits, Market Research. Techniques for visual inspection.

UNIT II

Application and economic benefits, Signature analysis- online and off-line techniques, Various condition Monitoring (CIV) techniques- Vibration monitoring and analysis, Measuring vibration, Frequency, Phase and vibration analysis, Complex vibration, Velocity RMS, Highfrequency detection systems. The time domain, the frequency domain, the frequency domain, fundamentals of vibro-acoustical condition monitoring, Wear and vibro-acoustic phenomena in machines. Condition assessment, system residual life and Symptom reliability. Commercial application of vibration monitoring, Shock Pulse Method.

UNIT III

Oil analysis including wear debris and contaminant monitoring. Performance monitoring, Acoustic emission and other techniques, Non-Destructive techniques, Ultrasonic testing, thermography etc. Application and choice of method, Computer aided monitoring including expert systems. Practical applications of diagnostic maintenance, Condition monitoring of mechanical and electrical machines. Case studies.

Text books:

1. Williams, I.H. Davies, A. and Drake, P, "Condition based maintenance & Machine Diagnostics", Chapman & Hall, 1st Edition, London, 1994.

Reference books:

1. Davies, A., "handbook of condition monitoring", Chapman & Hall, London, 1998.
2. Higgins, L.R. and Morrow, L.C., " Maintenance Engineering HIE", McGraw Hill, NY 1977

Course No: TMM-202 LUBRICANT SELECTION AND APPLICATIONS CL P (3 3 0)

Course topics:

UNIT I

Introduction, liquid lubricants, mineral oils, classification, types of crude petroleum, classification by viscosity index, hydrocarbon types, physical properties, refining, synthetic Oils, Di-Esters, Polyol Esters, Polyglycols, Phosphate Esters, Silicones, Silicate Esters and disiloxanes, Polyphenyl Ethers, C-Ethers, other organic liquids, Liquid glasses, liquefied oxides, liquid metals, greases, types of greases, soap base or thickener-lime, sodium and calcium etc, greases containing esters, silicones, consistency and grease selection, tribological implications, environmental issues.

UNIT II

Solid lubricants, Molybdenum disulphide and similar compounds, Graphite, Calcium fluoride and barium fluoride, graphite fluoride, polymers, metals as solid lubricants, other inorganic solid lubricants, self-lubricating composites, PTFE composites, Molybdenum disulphide composites, graphite composites, calcium fluoride composites, physical and chemical properties of lubricants.

UNIT III

Viscosity of lubricants, effect of temperature, pressure and shear rates on viscosity, measurement of viscosity, relative density, specific heat and thermal conductivity, acidity and alkalinity, oxidation stability. Flash point, foaming, pour point, demulsibility, extreme pressure additives. Lubrication between the piston rings and cylinder wall of a running engine, effect of speed, effect of viscosity and temperature, lubrication between a journal and bearing, effect of load, speed, viscosity and temperature, effect of temperature on lubricant films.

Text books:

1. Bhushan Bharat " Introduction to tribology" John Wiley & sons, Inc, 2002
2. Lansdown, A.R, " High temperature lubrication" Mechanical Engineering Publications Limited London, 1994

Reference books:

1. Bowden, F., Tabor, D., "The friction and lubrication of solids" Clarendon Press. Oxford 1986

Course No: MSD204WEAR ANALYSIS AND CONTROL CL P(3 3 0)

Course topics:

UNIT I

Introduction to wear control, types of wear, Adhesive wear, two-body and three-body abrasive wear, erosive wear, cavitation wear, etc. Tribo systems and tribo-elements, Measurement of Surface roughness Re, Rz, Experimental studies on friction on various tribo systems using pin-on-ring (POR) and pin-on-disc (POD) machines etc. Sample preparation, wear measurement of various tribo-elements using POR and POD machines. Calculation of wear volume and wear coefficient, comparison with existing data.

UNIT II

Diagnosis of wear mechanism using optical microscopy and scanning electron microscopy etc., Wear resistant materials, wear resistant coatings, eco-friendly coatings designing for wear, Systematic wear analysis, wear Coefficients, filtration for wear control.

UNIT II

Component wear, bushings, lubricated piston rings and Cylinder bore wear, dry piston rings, rolling bearings, seal wear, gear wear, gear couplings, wear of brake materials, wear of cutting tools, chain wear. Boundary lubrication, Hydrodynamic lubrication, EHD lubrication.

With case studies.

Text books:

1. Czichos, H., "Tribology.A system approach to the science &technology of friction, lubrication and wear", Series 1, Elsevier Publications 1982.
2. Glaeser,W. A., "Tribology series - Vol. 20," Elsevier Publications, 1992.
3. Neale, M.J., "The Tribology Hand Book," Butterworth Heinemann, London, 1995.

Reference books:

- 1.Peterson, M. B., Winer, W.O., "Wear Control Handbook," ASME, NY 1980.
2. Cameron A., "The principles of Lubrication", Longman, London,2000

Course No:TMM 20*

DESIGN FOR MAINTENANCE

C L P (3 3 0)

Course topics:

UNIT I

Overview of Maintenance, System Approach to Maintenance & Maintainability, Systematic design Approach to Maintainability, Maintainability at System conceptual design Stage (CDS). Introduction to Graph theory and fuzzy decision making at CDS for Maintainability.

UNIT II

Identification of Maintainability Parameters/attributes, Accessibility of critical components, Diagnosability, identification & Isolation of fault, Built in diagnostic for fault detection Optimum selection of maintenance systems, Design for condition monitoring, Design of Plant and machinery for a given maintenance strategy, Design for environment friendly maintenance, Standardization and interchangeability

UNIT III

Life cycle costing for optimum design and selection, Maintenance Logistics (facilities and resources), Human and safety factor, Design for maintenance through internet based technology (on-site and off-site); Developing reliable maintenance system, Design for simplicity and ease of maintenance, Design complexity versus maintenance complexity for enhanced availability" Fail safe design, FMEA, FMECA for design of failure free systems, Case studied from industries.

Industrial visits

Text books:

1. Dhillon, B.S., "Engineering Maintainability", Gulf publishing company, Houston Texas, USA, 1999

Reference books:

1 Higgins, L.R. and Morrow, L.c., " Maintenance Engineering H/B", McGraw Hill, NY, 1977.

Course No:TMM 20*

VALUE ENGINEERING

C L P (3 3 0)

Course topics:

UNIT I:

Introduction to value engineering (VE) & value analysis (VA), Life Cycle of a product, Methodology of VE, reasons for the existence of unnecessary costs. Quantitative definition of Value, use Value and Prestige value, Estimation of product Quality/Performance, types of Functions, relationship between use functions and Esteem Functions in product design, functional cost and functional worth, effect of value improvement on profitability, Tests for poor Value, Aims of VE systematic Approach.

UNIT II

Elementary introduction to V.E job plan/ functional approach to value improvement, various phases and techniques of the job plan, factors governing project selection, Types of projects, Lifecycle costing for managing the total value, concepts in LCC, Present value concept, Annuity concept, net present value, Pay Back period, internal rate of return (IRR) on investment, Example sand Illustrations. Creative thinking and creative judgement, positive or constructive discontent, Tangible and intangible costs of implementation, false material, labour and overhead saving, VE/VA yardsticks, relationship between savings and probability of success, Reliability Estimation, system Reliability, Reliability elements in series and parallel.

UNIT III

Phases and techniques of Value engineering Job plan:

General Phase, Information phase, Function phase, Creativity/Speculation Phase, Evaluation Phase, Investigation Phase and Recommendation Phase: Value improvement recommendation theory, determination of cut-off point (cop), road blocks in implementation. Decision Matrix/Evaluation Matrix, Quantitative comparison of Alternatives, Estimation of weights factors and efficiencies, utility transformation functions, bench marking, perturbation of weight factors (sensitive, analysis), Examples.

FAST Diagramming: Critical path of functions, HOW, WHY & WHEN Logic, Supporting and all time functions. **Term paper on recent advances in the field.**

Text Book:

1. Arthur E. Mudge, "Value Engineering- A Systematic Approach", McGraw Hill BookCo.1971.

Reference Books:

1. Miles L.D., "Techniques of value Analysis and Engineering", McGraw Hill Book Co. New York, 1970.
2. ASTME-American society for Tool and Manufacturing Engineers," Value engineering in Manufacturing", Prentice Hall 1967

Course No: MSD 20[#] ADVANCED MANUFACTURING SYSTEMS C L P (3 3 0)

Course topics:

UNIT I

Advanced manufacturing system concepts, Manufacturing automation, Programmable and hard automation. Design Automation, Application of CAD to manufacturing systems, Design for manufacturing and assembly. Computer Aided Engineering Analysis, Computer Aided Engineering evaluation. Rapid Prototyping, Stereo lithography, Selective laser sintering, FDM, laminated objected manufacturing, Polyjet technology. Robots, their classifications and Applications. Introduction to Robot programming. PLC's and their applications.

UNIT II

Introduction to Micro/ Nano machining, Principles of machining. Mechanics of Micromachining. Abrasive Micro machining. Diamond Micro- grinding/turning. Ultrasonic Micromachining. Electro-discharge Micro-machining, Laser Micro-machining, Electrochemical, Micro-machining, Chemical Micro-machining, Ion Beam Machining, Electron Beam Machining, Elastic emission machining, Abrasive flow finishing, Magnetic Abrasive finishing, Magneto rheological abrasive flow finishing, Magnetic float polishing

UNIT III

Introduction to Micro fabrication, microelectronic and micromechanical devices, Crystal Growing and wafer preparation, High resolution lithography Diffusion and Ion Implantation. Etching Metallization and testing, Wire bonding and packaging, Yield and reliability of chips, PCB's, The L I G A, Micro fabrication process, Solid free form fabrication of devices, Measuring techniques for micro features, Measuring techniques for nano features, Microhardness tester, Laser scanners, Robustness and selection of manufacturing processes, Factories of future.

Term paper on recent advances in the field.

Text Books

1. Degarmo, E.P., Black, J.T. and Kohser, R.A, "Materials and Processes in Manufacturing", Prentice Hall of India, 2006.
2. Anthony, E., "Fluid Power with applications", Prentice Hall of India, 2007.

Reference Book:

1. Serop K. Steven, "Manufacturing Processes for Engineering Materials", Prentice Hall of India, 2004.

Course No: TMM-301 COMPUTER APPLICATIONS IN MAINTENANCE CL P (3 2 2)

Course topics:

UNIT I

Introduction to information systems, maintenance management information system (MMIS) system analysis and design Role of computer in maintenance management ,mainatenance overview.

UNIT II

Basics of software engineering. Fundamentals of Programming with specific emphasis of object oriented paradigms. Study of various available software and their implementation for maintenance.System analysis of various maintenance strategies, activities/ modules and their implementation.

UNIT III

Evaluation and optimum selection of computerized maintenance management System(CMMS), Knowledge based approach to maintenance management. Expert system, 1 network for CMMS, Software consideration for design of CMMS, Maintenance through met based technology, Commercially available Softwares, Case studies.

Text books:

1. Willaims, IH., Davies, A. and Drake, P, "Condition based maintenance &Machine diagnostics", Chapman &Hall, 1 stEdition, London, 1994.

Reference books:

1. Higgins, L.R. and Morrow, L.c., " Maintenance Engineering I-II B " , McGraw Hill,NY, 1977.

Course No:MSD 301 DESIGN OF TRIBOSYSTEMS C L P(4 3 2)

Course topics:

UNIT I

Application of system concepts to tribology, Function of Tribomechanical systems, Structure of Tribo-mechanical systems, Tribological interaction, Functional plane, mechanical work plane, thermal plane and material plane. Role of tribo processes in mechanical systems, Wear as a system property. Contact Mechanics, number of bodies taking part in contact process, macro geometry of bodies, Deformation mode; elastic , plastic and elastic-plastic, Types of relative motion; static contact, rolling contact, sliding contact, contact physics and geometry,contamination layer, absorbed gas layer, oxide layer, work hardened layer, metal substrate.

UNIT II

Materials for various tribo-components, materials for plane bearing, materials for gear, materials for brakes, clutches, materials for Internal combustion engines, ceramics and special alloys, cermets, polymer materials, selection considerations in design.

UNIT III

Design of various tribo-elements; such as: Plane bearing, Gear, Seals, Piston and cylinder, Friction devices, cutting tools, chains. Design of lubrication systems.

Text Book:

1. Czichos, H., “Tribology: A system approach to the science & technology of friction, lubrication and wear,”– Tribology Series 1, Elsevier Scientific Publishing Company, Amsterdam, Netherland, 1978.

Reference Books:

1. Peterson, M. B., Winer, W. O., “Wear Control Handbook,” ASME, N. Y., 1992.
2. Glaeser, W. A., “Tribology: Materials for Tribology,” –Tribology series – Vol. 20, Elsevier,N. Y. 1992.
1. Stolarski, T., “Tribology in Machine Design”, Butterworth-Heinemann, N. Y., 1990.