M. Tech. DEGREE

THERMAL POWER ENGINEERING

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(2009 -2010)

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015, INDIA.

M.Tech. THERMAL POWER ENGINEERING

The total credits required for completing the M.Tech. Programme in Mechanical Engineering is 61

SEMESTER I

Code	Course of Study	L	T	P	C
MA 609	Mathematical Methods	3	0	0	3
ME 601	Fuels, Combustion and Emission Control	3	0	0	3
ME 603	Advanced Fluid Mechanics	3	0	0	3
ME 605	Advanced Heat Transfer	3	0	0	3
ME 607	Analysis of Thermal Power Cycles	3	0	0	3
	Elective I	3	0	0	3
	Total	**18**	**0**	**0**	**18**

SEMESTER II

Code	Course of Study	L	T	P	C
ME 602	Fluid Mechanics of Turbomachines	3	0	0	3
ME 604	Instrumentation	3	0	3	4
ME 606	Computational Fluid Dynamics	3	0	0	3
	Elective II	3	0	0	3
	Elective III	3	0	0	3
	Elective IV	3	0	0	3
	Total	**18**	**0**	**3**	**19**

SEMESTER III

ME 747	Project Work – Phase I	0	0	0	**12**

SEMESTER IV

ME 748	Project Work – Phase II	0	0	0	**12**

Total Credit 61

LIST OF ELECTIVES

SEMESTER I

ELECTIVE – I

Code	Course of Study	L	T	P	C
ME 631	Analysis and Design of Pressure Vessels	3	0	0	3
ME 633	Advanced IC Engines	3	0	0	3

SEMESTER II

ELECTIVE - II, III & IV

Code	Course of Study	L	T	P	C
ME 632	Energy Conservation, Management, and Audit	3	0	0	3
ME 634	Advanced Refrigeration and Air Conditioning	3	0	0	3
ME 636	Boiler Auxiliaries and Performance Evaluation	3	0	0	3
ME 638	Heat Transfer Equipment Design	3	0	0	3
ME 640	Tribology	3	0	0	3
ME 642	Finite Element Method in Heat Transfer Analysis	3	0	0	3
ME 644	Alternative Fuels for I.C Engines	3	0	0	3
ME 671	Environmental Pollution Control	3	0	0	3
	Any other Elective offered by other department	3	0	0	3

MA 609 MATHEMATICAL METHODS (3 – 0 – 0) 3

Calculus of variations - Euler's equation - Variational problems in parametric form - Natural boundary condition – Conditional Extremum - Isoperimetric problems.

Direct methods in Variational Problems - Euler's finite difference method - Rayleigh -Ritz method - Galerkin's method - Kantorovich's method.

Integral equations - Conversion of BVP to integral equations using Green's Function - Fredholm equation with separable kernels – Solution of Fredholm and Volterra equations by the method of Successive approximations.

Finite difference scheme for elliptic, parabolic, and hyperbolic partial differential equations.

Introduction to Finite Element Method - Rules for forming interpolation functions - Shape functions Application to fluid flow and heat transfer problems.

References

1. *DESAI, C.S., and ABEL, J. P., Introduction to Finite Element Method, Van Nostrand*
1. *Reinhold.*
2. *ELSEGOLTS, L., Differential Equations and the Calculus of Variations, Mir Publishers.*
3. *GREWAL, B.S. , Higher Engineering Mathematics, Khanna Publishers.*
4. *HILDEBRAND, P.B., Method of Applied Mathematics, Prentice Hall.*
5. *VENKATARAMAN, M. K., Higher Mathematics for Engineering and Science, National Publishing Company.*

ME 601 FUELS, COMBUSTION, AND EMISSION CONTROL (3 – 0 – 0) 3

Types of fuels and their properties - Coal characterization - Combustion chemistry - Stoichiometry Heat of reaction - Calorific value - Adiabatic flame temperature - Equilibrium - Mass transfer.

Chemical kinetics - Important chemical mechanisms - Simplified conservation equations for reacting flows - Laminar premixed flames - Simplified analysis.

Factors influencing flame velocity and thickness flame stabilization - Diffusion flames - Introduction to turbulent flames.

FBC - Different types of FBCs - Models for droplet and Carbon particle combustion.

Emissions - Emission index - Corrected concentrations - Control of emissions for premixed and non-premixed combustion.

References

1. Turns, S.R., *An Introduction to Combustion - Concepts and Applications, 2nd* ed., McGraw-Hill, 2000.
2. Sharma, S.P. and Mohan, C., *Fuels and Combustion,* Tata McGraw-Hill, 1987.
3. Sarkar. S., *Fuels and Combustion,* Orient Longman, 2005.

ME 603 ADVANCED FLUID MECHANICS (3 – 0 – 0) 3

Review of Basic concepts- Reynold's transport theorem, Fluid kinematics - Physical conservation laws - Integral and differential formulations.

Navier-Stokes and energy equations - Dimensionless forms and dimensionless numbers - Solution of Navier-Stokes equations.

Two-dimensional Potential flows - Different types of flow patterns. Boundary layer theory - Blasius solution - Momentum integral approach.

Turbulent flows - Reynolds equation - Prandtl and von Karman hypothesis- Universal velocity profile near a wall- flow through pipes

Boundary layer concept- Boundary layer thickness- prandtl's equations-blassius solution-skin friction coefficient.

References

1. Currie, LG., *Fundamental Mechanics of Fluids, 3rd* ed., CRC Press, 2002.
2. White, P.M., *Viscous Fluid Flow, 2nd* ed., McGraw-Hill, 1991.
3. Ockendon, H. and Ockendon, J., *Viscous Flow,* Cambridge Uni. Press, 1995.

ME 605 ADVANCED HEAT TRANSFER (3 – 0 – 0) 3

Transient heat conduction - Exact solution - Use of Heisler and Grober chart-Integrated method.

Extended surfaces - Steady state analysis and optimization-Radial fins of rectangular and hyperbolic profiles- longitudinal fin of rectangular profile radiating to free space.

Thermal boundary layers - Momentum and energy equations -Internal and external flows- Forced convection over cylinders, spheres and bank of tubes.

Heat transfer with phase change – condensation and boiling heat transfer- Heat transfer in condensation, Effect of non-condensable gases in condensing equipments. Flow boiling correlations.

Radiative exchange in furnaces-Radiation characteristics of particle systems, Thermal radiation of a luminous fuel oil and gas- Soot flame- overall heat transfer in furnaces.

References

1. Ozisik, M.N., *Heat Tran5fer - A Basic Approach,* McGraw-Hill, 1987.
2. Incropera, P.P. and Dewitt, D.P., *Fundamentals of Heat and Mass Transfer, 5th* ed., John Wiley, 2002.
3. Kakac, S. and Yener, Y., *Convective Heat Transfer,* CRC Press, 1995.
4. Kraus, A.D., Aziz, A., and Welty, J., *Extended Surface Heat Tran5fer,* John Wiley, 2001.

ME 607 ANALYSIS OF THERMAL POWER CYCLES (3 – 0 – 0) 3

Steam power plant cycle - Rankine cycle - Reheat cycle - Regenerative cycle with one and more feed heaters - Types of feed heaters - Open and closed types - Steam traps types.

Cogeneration - Condensing turbines - Combined heat and power - Combined cycles - Brayton cycle Rankine cycle combinations - Binary vapour cycle.

Air standard cycles - Cycles with variable specific heat - fuel air cycle - Deviation from actual cycle.

Brayton cycle - Open cycle gas turbine - Closed cycle gas turbine - Regeneration - Inter cooling and reheating between stages.

Refrigeration Cycles - Vapour compression cycles - Cascade system - Vapour absorption cycles - GAX Cycle.

References

1. Culp, R., *Principles of Energy Conversion,* McGraw-Hill, 2000.
2. Nag. P.K., *Power Plant Engineering, 2nd* Tata McGraw-Hill, 2002.
3. Nag. P.K., *Engineering Thermodynamics, 3rd* ed., Tata McGraw-Hill, 2005.
4. Arora, C.P., *Refrigeration and Air Conditioning, 2nd* ed., Tata McGraw-Hill, 2004.

ME 602 FLUID MECHANICS OF TURBOMACHINES (3 – 0 – 0) 3

Introduction and cascades - Two-dimensional cascades - Analysis of cascade forces – Energy losses – Cascade correlation – Off design performance.

Power generating machine I - Axial flow turbines- Stage losses and efficiency – Soderberg's correlation – Turbine flow characteristics

Power absorbing machine I - Axial flow compressors, pumps, and fans – Three dimensional flow in axial turbo machines – theory of radial equilibrium – actuator disc approach – Secondary flows

Power absorbing machine II - Centrifugal pumps, fans, and compressors – slip factor – optimum design of centrifugal compressor inlet choking in a compressor stage.

Power generating machine II - Radial flow turbines, Loss coefficients – off design operating condition – clearance and windage losses 90 deg IFR turbines.

References

1. Dixon, S.L., *Fluid Mechanics and Thermodynamics of Turbomachinery, 5th* ed., Butterworths Heinemann, 2005.
2. Csanady, G.T., *Theory of Turbomachines,* McGraw Hill, 1964.
3. Prithvi Raj, D. and Gopalakrishnan, G., *A Treatise on Turbomachines,* Scitech Publication, 2003.

ME 604 INSTRUMENTATION (3 – 0 – 0) 3

Generalized instrumentation system – Error theory – Calibration of instruments – Range – resolution – Span – Linearity, Sensitivity- Signal conditioning systems.

Static and dynamic characteristics of instruments zero order, first order, second order instruments.

Error analysis - Uncertainty propagation – Oscilloscope for analysis of dynamic and transient events.

Principles and analysis of measurement systems used for measurement of flow, power, pressure, and temperature.

Basics of control system - Types of control – proportional control, Derivative control, Integral control, PID control-Programmable logic controllers.

References

1. Doebelin, E.O., *Measurement Systems - Application and Design, 5th* ed., McGraw-Hill, 2004.
2. Beckwith, T.G., Buck, L., and Marangoni, R.D., *Mechanical Measurements,* Narosa Pub. House,1987.
3. Hewlett Packard, *Practical Temperature Measurements* - Application Note 290, 1995.

PRACTICAL

Use of oscilloscope for measurement of dynamic parameters - PV diagram of compressors and IC engines - Comparison of flow measuring instruments - Measurement of static and dynamic characteristics of instruments.

ME 606 COMPUTATIONAL FLUID DYNAMICS (3 – 0 – 0) 3

Classification of partial differential equations - Discretization methods - finite difference and finite volume formulations –classificatrion of PDES.

Numerical solution of elliptical equations - Linear system of algebraic equations – Iterative solution of system of linear equation.

Model Equations – Wave equations - Numerical solution of parabolic equations - Stability analysis – Advanced shock capturing schemes.

Solutions of convection - Diffusion equation – Conservative and non-conservative schemes – concept of artificial viscosity and Numerical Diffusion.

Navier-Stokes equations and algorithms; Basics of grid generation- Numerical solution of hyperbolic equations - Burgers equation generation.

References

1. Tannehill, J.c., Anderson, D.A., and Pletcher, R.H., *Computational Fluid Mechanics and Heat Tran5fer, 2nd* ed., Taylor & Francis, 1997.
2. Hoffmann, K.A. and Chiang, S.T., *Computational Fluid Dynamics for Engineers,* Engineering Education Systems, 2000.
3. Peyret, R. and Taylor, T. D., *Computational Methods for Fluid Flow,* Springer-Verlag, 1983.

ELECTIVE - I

ME 631 ANALYSIS AND DESIGN OF PRESSURE VESSELS (3 – 0 – 0) 3

Establishment of design conditions – Fracture Mechanics – Heads, Basic shell thickness - Reinforcement of openings – Special components like flange, tube plate, supports.

Cylindrical shells – Thick cylinders- Lame's solution - Theories of breakdown of elastic action – Unrestrained solution – Lateral loading – General loading. Axisymmetric loading - Membrane solutions - Edge bending solutions - Flexibility matrix.

Application of general analysis – Flat closure plates –conical heads and reducers – hemispherical and torispherical, ellipsoidal heads.

Development of cracks - Fracture mechanics - Corrosion - Selection of working stress for ductile and brittle materials.

Finite element analysis for high pressure and high temperature components.

References

1. Bickell, M.B. and Ruiz, c., *Pressure Vessel Design and Analysis,* MacMillan, London, 1967.
2. Den Hartog, J.P., *Advanced Strength of Materials,* McGraw-Hill, 1949.
3. Timoshenko, S., *Strength of Materials,* Van Nostrand, 1986.

ME 633 ADVANCED IC ENGINES (3 – 0 – 0) 3

Engine design and operating parameters – Thermo chemistry of fuel air mixtures- properties of working fluids.

Ideal model of engine cycles – cycle analysis with constant specific heats – Volumetric efficiency – Super charging and Turbo charging

Fuel intake systems and combustion in SI and CI engines – Carburetor an fuel injection systems – Squish prechamber engine flows.

Pollutant formation and control in IC engines - Types of diesel combustion system – Fuel spray behavior – Ignition delay.

Engine friction and lubrication – measurement of friction – fluid mechanics based multi dimensional models – Engine operating characteristics.

References

1. Heywood, J.B., *Internal Combustion Engine Fundamentals,* McGraw-Hill, 1988.
2. Taylor, C.P., *The Internal Combustion Engines in Theory and Practice,* Vol-2, MIT press, 1985.
3. Ganesan, V., *Internal Combustion Engines, 2nd* ed., Tata McGraw-Hill, 2003.

ELECTIVES II, III & IV

ME 632 ENERGY CONSERVATION, MANAGEMENT, AND AUDIT (3 – 0 – 0) 3

Energy Scenario - Basics of Energy and its various forms - Energy Management and -Audit - Material and Energy Balance -Energy Action Planning-Financial Management -Project Management -Energy Monitoring and Targeting -Global Environmental Concerns

Energy Efficiency in Thermal Utilities - Fuels and Combustion-Boilers-Steam System-Furnaces - Insulation and Refractory -FBC Boilers -Cogeneration -Waste heat recovery

Energy Efficiency in Electrical Utilities-Electrical Systems-Electric Motors-Compressed Air System-HVAC and Refrigeration System-Fans and Blowers-Pumps and Pumping System-Cooling Tower-Lighting System-Diesel Generating System-Energy Efficient Technologies in Electrical Systems

Energy Performance Assessment for Equipment and Utility systems -Boilers-Furnaces-Cogeneration, Turbines (Gas, Steam)- Heat Exchangers-Electric Motors and Variable Speed Drives-Fans and Blowers-Water Pumps-Compressors

HVAC Systems-Lighting Systems-Performing Financial Analysis-Applications of Non-Conventional and Renewable Energy Sources-Waste Minimization and Resource Conservation

Reference

1. *Guide book for National Certification Examination for Energy Managers and Energy Auditors,* Bureau of energy efficiencies, 2005.

ME 634 ADVANCED REFRIGERATION AND AIR CONDITIONING (3 – 0 – 0) 3

Actual vapor compression system - Multipressure vapour compression system - Environment friendly refrigerants – cascade system.

Absorption refrigeration system – Three fluid absorption system – comparison of absorption with compression system - Analysis of multistage systems

Advanced psychrometric calculations - Cooling load calculations – Determination of U factor – short method calculation

Low temperature refrigeration - Joule Thompson coefficient – liquefaction of air – hydrogen – helium - Applications of cryogenics.

Room air distribution – Friction losses in ducts - Duct design, Air filters clean rooms – Air curtain

References

1. Arora, c.P., *Refrigeration and Air Conditioning, 2nd* ed., Tata McGraw-Hill, 2004.
2. Stoeker, W.P. and Jones, J.W., *Refrigeration and Air Conditioning, 2nd* ed., Tata McGraw-Hill, 1982.
3. Manohar Prasad, *Refrigeration and Air Conditioning,* New Age International, 1996.
4. Gosney, W.B., *Principles of Refrigeration,* Cambridge Uni. Press, 1982.

ME 636 BOILER AUXILIARIES AND PERFORMANCE EVALUATION (3 – 0 – 0) 3

Boiler types - Efficiency calculation - Balance diagram – Boiler start up calculations –Boiler turbine matching – Power Plant balance diagram

Fuel and Ash handling Equipment – Crushers and Mills - Drum internals - Specification and selection.

Feed pumps – Different types, Specifications, Operation and maintenance aspects - Fans, blowers – Applications – Performance requirements, Selection, Operation and maintenance.

Dust cleaning equipment – Selection criteria – Design, operation and maintenance of electro static precipitators, Bag filters.

Soot blowers – Various types and their constructional features – Specifications – Selection – Operation and Maintenance.

References

1. *Modern Power Station Practice,* CEGB London, Pergamon Press, 1991.
2. Eck, B., *Fans,* Pergamon Press, 1973.
3. Shields, C.D., *Boilers, Types Characteristics and Functions,* McGraw-Hill, 1961.

ME 638 HEAT TRANSFER EQUIPMENT DESIGN (3 – 0 – 0) 3

Classification of heat transfer equipment - Design of shell and tube heat exchanger - Finned surface heat exchanger –Heat exchangers for special services – Fired heaters

Plate and spiral plate heat exchanger – plate heat exchanger for Dairy industry – Heat Pipes

Thermal design of heat exchange equipments such as Air pre-heaters , Economizer – Super heater and condensers.

Selection of compact heat exchangers.

Analysis and design of cooling towers.

References

1. Ganapathy, v., *Applied Heat Transfer,* Pennwell Books, 1982.
2. Kays, W.M. and London, A.L., *Compact Heat Exchangers,* McGraw-Hill, 1998.
3. Dunn, P. and Reay, D.A., *Heat Pipes,* Pergamon, 1994.
4. Kakac, S. and Liu, H., *Heat Exchangers,* CRC Press, 2002.

ME 640 TRIBOLOGY (3 – 0 – 0) 3

Introduction - Tribology in design, Tribology in industry. Lubricants- Properties- physical and chemical, Types of additives, extreme pressure lubricants. Lubrication-introduction, basic modes of lubrication

Friction - friction measurement, theory of friction. Wear: Types of wear, various factors affecting wear, measurement of wear, wear between solids and liquids, theory of wear.

Gas Lubrication. Lubrication in metal working: Rolling, Forging, Drawing and extrusion.

Solid tribological coatings and materials, – surface treatments –surface modification processes. Tribological properties of metallic and ceramic coatings.

Surface topography measurements - Electron microscope and friction and wear measurements - Use of transducers and instruments in Tribology- film thickness measurement using modern techniques – Development of test rigs for Tribology research.

References

1. Kenneth C Ludema, *Friction, Wear, Lubrication: A text book in Tribology*, CRC press, 1996.
2. G. W. Stachowiak, A. W. Batchelor and Gwidon Stachowiak, *Engineering Tribology*, Butterworth-heinemann, 2006.
3. S. K. Basu, S.N.Sengupta & B.B.Ahuja, *Fundamentals of Tribology*, Prentice –Hall of India Pvt Ltd , New Delhi, 2005.
4. J.A. Williams, *Engineering Tribology*, Oxford Univ. Press, 1994.

ME 642 FINITE ELEMENT METHOD IN HEAT TRANSFER ANALYSIS (3 – 0 – 0) 3

Introduction, Weighted Residual Methods, Shape functions, Coordinate systems, Numerical Integration.

Modeling of Heat Conduction, Variational Formulation, Galerkin's Approach for one dimensional and two dimensional problems

Introduction – A one dimensional Problem solved using a single element – Linear element, Quadratic element, the use of numerical integration. A one dimensional problem solved using an assembly of elements.

Time stepping methods for Heat Transfer – Galerkin's approach in Non-linear transient heat conduction problems.

Introduction, Basic Equations, Galerkin's Methods for steady Convection – Diffusion problems, Upwind Finite Elements in One Dimension, Heat Transfer in fluid flow between parallel planes, Convection on melting and solidification.

Laboratory Experiments

1. Basic problems in Heat Transfer Analysis using ANSYS
2. 1D, 2D and 3D conduction field problems
3. Convection problems
4. Heat Transfer in Fluid Flow
5. Convection on Melting and Solidification

References

1. H. R. Thomas, K. N. Seetharamu, Ken Morgan, R. W. Lewis, "*The Finite Element Method in Heat Transfer Analysis*", John Wiley & Sons Inc, 1996.
2. Roland W. Lewis, Perumal Nithiarasu and K.N. Seetharamu, *"Fundamentals of the Finite Element Method for Heat and Fluid Flow"*, Wiley; 1 edition, 2004.
3. J.N. Reddy and D.K. Gartling, *"The Finite Element Method in Heat Transfer and Fluid Dynamics",* CRC; 2 edition, 2000.

ME 644 ALTERNATIVE FUELS FOR I.C ENGINES (3 – 0 – 0) 3

Availability and Suitability to Piston Engines, Concept of conventional fuels, potential alternative fuels-Alcohol, Methanol, DEE/DME-Hydrogen, LPG, Natural gas, Producer gas, Bio-gas and vegetable oils-Use in IC engines-Merits and demerits of various fuels.

Technical Background of Diesel/Bio-diesel fuels-Oil feed stocks- Transesterification-Bio-diesel production from Vegetable oils and waste cooking oil-High blend levels of bio-diesel-Testing Bio diesel-Oxidation stability-Performance in Engines, Properties of bio-fuels and their importance in the context of IC Engines.

Initiation of combustion, flame velocities, Normal and abnormal combustion, Knocking combustion, pre-ignition-Knock and engine variables,-Features and design consideration of combustion chambers- stratified charge combustion- concepts of lean burn engines. Computation of heat release rates from cylinder pressure data. Spray formation and combustion in diesel engines. Heat release and heat transfer correlations for diesel engines.

Types-Air flow, Fluid flow, Temperature, Speed, Oxygen, Detonation, Position, Principle of operation, Arrangement and material. Cylinder pressure measurement.

Atmospheric pollution from piston engines, Global warming, Pollutant Formation in IC Engines-Emission measurement-control of Engine pollution–driving cycles and Emission standards. Emission measuring instrumentation including HC, CO, NOx, smoke and particulates.

References

1. John B.Heywood*, Internal Combustion Engine Fundamentals*, McGraw Hill Book Company, 1988.
2. Taylor, C.P., *The Internal Combustion Engines in Theory and Practice*, Vol-2, MIT press, 1985.
3. RichardL.Bechtold, *Automotive Fuels Guide Book*, SAE Publications, 1997.

ME 671 ENVIRONMENTAL POLLUTION AND CONTROL (3 – 0 – 0) 3

Air pollution - Classification and properties of Air pollutants - Sampling and analysis of air pollutants –Control of air pollution.

Dispersion of air pollutants - Gaussian plume model- Control of gaseous pollutants - Volatile organic compounds - Control of gaseous emission - Air pollution laws and standards.

Water pollution - Sampling and analysis of waste treatment – Advanced waste water treatments by physical, chemical, biological and thermal methods - Effluent quality standards.

Solid waste management - Classification and their sources - Health hazards - Handling of toxic and radioactive wastes - Incineration and verification.

Pollution control in process industries namely Cement, Paper, Petroleum and petrochemical, Fertilizers and distilleries, thermal power plants and automobiles.

References

1. Manster, G.M., *Introduction to Engineering and Science, 2nd* ed., Pearson Publishers, 2004.
2. Rao, E.S., *Environmental Pollution Control Engineering,* Wiley Eastern Ltd., 1991.
3. Mahajan, S.P., *Pollution Control in Process Industries,* Tata McGraw-Hill, 1985.
4. Crawford, M., *Air Pollution Control Theory,* TMH, 1976.