M.Tech. Degree

THERMAL POWER ENGINEERING

SYLLABUS
FOR
CREDIT BASED
CURRICULUM

Effective from 2006-07

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015.

INDIA

MAY 2006

NATIONAL INSTITUTE OF TECHNOLOGY - TIRUCHIRAPPALLI
DEPARTMENT OF MECHANICAL ENGINEERING

M.Tech. THERMAL POWER ENGINEERING

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

CODE	COURSE OF STUDY	L	T	P	C
	SEMESTER I				
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				
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

ME 631	Analysis and Design of Pressure Vessels
ME 632	Energy Conservation, Management, and Audit

SEMESTER II

ELECTIVE - II, III & IV

ME 633	Advanced IC Engines
ME 634	Advanced Refrigeration and Air Conditioning
ME 635	Boiler Auxiliaries and Performance Evaluation
ME 636	Heat Transfer Equipment Design
ME 637	Installation, Testing, and Operation of Boilers
ME 673	Environmental Pollution Control
MT 665	Non Destructive testing and Failure analysis
MT 667	Frontier Materials

Any other Elective offered by other department

SEMESTER I

MA 609 MATHEMATICAL METHODS

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 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

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

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- prandd'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

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

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.

SEMESTER II

ME 602 FLUID MECHANICS OF TURBOMACHINES

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

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

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

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 632 ENERGY CONSERVATION, MANAGEMENT, AND AUDIT

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

References:

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

ELECTIVES II, III & IV

ME 633 ADVANCED IC ENGINES

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.

ME 634 ADVANCED REFRIGERATION AND AIR CONDITIONING

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 635 BOILER AUXILIARIES AND PERFORMANCE EVALUATION

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 636 HEAT TRANSFER EQUIPMENT DESIGN

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 637 INSTALLATION, TESTING, AND OPERATION OF BOILERS

Installation of boilers – Supporting structures, Sequence of Erection, HSFC Bolts – Drum lifting alignment - Provision for expansion of water walls

Erection of Ducts - ESP - APH - and fans- Alignment. Erection of ducts and dampers – Cold pull.

Lining and Insulation – Material characteristics and selection - Procedure for mounting Gaskets for erection of boilers.

Boiler commissioning activities – Drying out –Boiling out – Chemical cleaning initial operation – Abnormal operations – precautions –shutting down

Codes for Testing, Inspection and cleaning – Boiler pressure parts – Life estimation for very old boilers – Thermal performance test and capacity restoration.

References:

1. *Erection of Boilers and Auxiliary Equipment,* Manuals Prepared by B.H.E.L., Tiruchirappalli, 1990.

ME 673 ENVIRONMENTAL POLLUTION AND CONTROL

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.

MT 665 NON DESTRUCTIVE TESTING AND FAILURE ANALYSIS

NDT Vs destructive testing – advantages and limitations – different types of NDT

Detailed discussion of LPT, MPT and radiography

Eddy current and ultrasonic techniques

Comparison and selection of different NDT methods – statistical significance – reliability aspects – need for multiple NDT procedures in critical components – concept of NDE

Concept of failure analysis – methodology, approaches and tools – design and material improvements derived from case studies – fracture mechanics approach

References:

1. Baldev Raj, Jayakumar, Thavasimuthu. M., *Practical Non destructive testing*, Narosa Publishing, 1997.
2. Das. A.K., Metallurgy of failure analysis, Tata McGraw Hill, 1992.

MT 667 FRONTIER MATERIALS

Trends and developments in materials – historical perspective – challenging applications

Need for microstructurally engineering materials – top down and bottom up approaches in assemblage of materials / particles

Detailed discussion on specific material systems – metallic glasses – processing conditions – bulk metallic glasses

Stainless steel and special steels – low-density high strength alloys – super alloys – cryogenic materials

Shape memory alloys – FGM's – biomaterials – nano materials

References:

1. Polmear. I. J., *Light Alloys, Metallurgy of Light Metals*., 3rd edition, Arnold 1995.
2. Leslie . V. C., *Physical Metallurgy of steels*, McGraw Hill, 1982.