**Programme Educational Objectives (PEOs)**

“To develop skilled manpower in the field of turbomachines with the knowledge of transport processes through the turbomachine passage, analytical, numerical and experimental tools for design, operation, performance evaluation and innovative research in the area of turbomachines”

**PEO1:**
To impart fundamental understanding of transport processes and mathematical modeling of these transport processes through turbomachine passages

**PEO2:**
To train the students with analytical and numerical tools required for performance evaluation and innovative research in the area of rotodynamic machines

**PEO3:**
To educate the students with knowledge of experimental techniques and instruments required to carry out research in the field of turbomachines

**PEO4:**
To provide knowledge of performance evaluation, operation and maintenance of rotodynamic machines

**PEO5:**
To impart knowledge on conceptual design of different components of thermal and hydroturbomachines

**PEO6:**
To inculcate self learning skills and communication skills towards overall personality development of the student
# COURSE STRUCTURE FOR M. TECH. (TURBOMACHINES)

## SEMESTER – I

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SEMESTER – I

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1. Introduction to FEM
4. Interpolation Functions, Element Matrix, Assembly and Boundary Conditions.
5. Condensation and Solution Algorithms.
6. Introduction to non-linear finite element methods

Reference:

• Basic concepts of Measurement
• Statistical Analysis of Experimental Data Method of Least Squares, Uncertainty Analysis.
• Response characteristics of Instruments – 1st & 2nd order instrument.
• Transducers, Vibration & Noise measurements.
• Theory of strain gauges
• Advance & Specific measurements – Stress & Strain Measurement by Photo Elastic Bench, Hotwire & Laser Doppler Anemometry.
• Thermal & Transport property measurement, Thermo gravimetry, Gas Chromatography, Air Pollution & Nuclear radiation measurement.
• NDT, Radiography, Ultrasonography
• Wind Tunnel Testing
• Data Acquisition System

Reference:
• Cartesian Tensors
• Basic Concepts: Types of fluids and basic equations of flow, basic concepts in laminar and turbulent flows.
• Equations Governing Fluid Motion: Navier stokes equations, Boundary layer equations, Exact solutions of N-S equations, Flow between concentric rotating cylinders, Parallel flow of a powder – law fluid.
• Potential Theory: Kelvin's theorem, source, sink, vortex and doublet, development of complex potentials by super position, Singularities – plane flow past bodies – Dirchlet theorem - Conformal transformation thin aerofoil theory.
• Laminar Boundary Layers: Blasius solution, Boundary Layers with non-zero pressure gradient, separation and vortex shedding.
• Turbulent Flow: Mechanism of turbulence, derivation of governing equations for turbulent flow, K-E model of turbulence, Universal velocity distribution law and friction factor, Kinetic energy of the mean flow and fluctuations, Relaminarization.
• Experimental Techniques: Pressure tubes, Thermal anemometers, Laser – Doppler anemometers, P-I velocimeter.
• Computational Fluid Dynamics: Philosophy of CFD, Governing equations, thin derivation and physical meaning, mathematical behaviour of P.D.E. and its impact on CFD, Finite difference scheme, Grid generation and transformation, Application to FEM and finite volume method for CFD Problems.

Reference:
Modes of Heat Transfer.


Boiling & Condensation.


Reference:

Basic concepts of energy analysis of thermal systems

Basic Exergy concepts:
- Classification of forms of exergy, concepts of exergy, exergy concepts for a control region, physical exergy, chemical exergy, exergy concepts for closed system analysis, Non-flow exergy.

Elements of plant Analysis:
- Control mass analysis, control region analysis, criteria of performance, pictorial representation of exergy balance, exergy based property diagram

Exergy analysis of processes:
- Expansions process, compression processes, heat transfer process, Mixing & separation process, Chemical process including combustion etc.

Energy Analysis of Thermal Systems:
- Gas turbine plant-Thermal Power Plant-Cogeneration Plant-Captive power plant-
- Combined cycle Power plant-Refrigeration Plant-Chemical Plant-Lunde air liquification plant, Heat Exchanger etc.

Reference:

• Single and Multivariable optimization methods, constrained optimization methods, Kuhn-Tucker conditions-Necessary & Sufficiency theorems.
• Linear programming-Traveling salesman problem and Transshipment problems - post optimization analysis.
• Integer programming All integer, Mixed integer and zero-one programming
• Geometric programming – concept – degree of difficulty – solution of unconstrained & constrained non linear problems by geometric programming.
• Dynamic programming.
• Probabilistic Technique – Trade offs between capital & energy using Pinch Analysis.
• Energy-Economy models –Scenario Generation.

Reference:
- Ideal Cycles, Combustion and Combustion Chambers, Component Losses, performance calculations Comparison with practical Cycles.
- Rocket Propulsion, Ramjet Engines.

Reference:
• Review of fundamentals - Isentropic, adiabatic, Fanno line and Rayleigh line flows.
• Beltrami flows - Cylindrical stream surfaces - Axisymmetric Beltrami flows - of free - vortex type of forced - vortex type and with constant flow angle - Mass flow rate through annulus - Chocking of flow through annulus.
• Potential flows - Absolute potential flows - flow equations.

• Normal shock - Governing equations - strength of shock waves - schcks in nozzles.

• Supersonic flows - Method of characteristics one and two dimensional isentropic flows - two dimensional, irrotational, isentropic, supersonic flow - Design of curved passages - supersonic nozzles - Supersonic cascades.

• Axi-symmetric flows in rotating and stationary PASSAGE - Geometry of blade surfaces - Equilibrium conditions of flow - Influence of conditions at leading edge of blades - Flow conditions at rotor inlet and at rotor outlet - Flow in rotors with arbitrary blades - Methods of solution - correction for finite spacing and thickness of blades - Experimental results.

• Quasi two-dimensional flows in turbomachines - Quasi two dimensional flow on surface of revolution - Irrotational flows on cylindrical stream surfaces - Blade force and circulation - systems of vortex lines as replacement for cascades - Axial cascades replaced by vortex sheet - Biot - Savart's law applied to vortex system for cascade with non-radial blades.

REFERENCES:

• Rotodynamic pumps - pump parameters - similar pumps - non-dimensional parameters - Specific speed - pump classification - different types - ranges of operation.


• Testing of pumps - test rigs - standard instrumentation - operational characteristics.

• Hydraulic turbines - basic parameters - principles of similarity - model turbines - Unit quantities and specific speed classification range of utilization - Constructional details of water turbines - Reaction turbines - propeller - Kaplan, bulb and Francis


• Basic theory of reaction turbine - Velocity triangles and their correction - aerofoil theory - flow through different flow passages - volute, guide apparatus, runner and draft tube - hydraulic, volumetric and mechanical losses - energy balance - regulation of discharge - off-design performance - Forces and moments of guide vanes and adjustable blades of runner - axial thrust - cavitation in turbines - Thoma's coefficient - Location of turbine above the tail race.

• Theory of pelton wheel - action of jet on the buckets - flow on bucket surfaces - Hydrodynamic forces and torque on the runner - losses - energy balance.

• Testing of model turbines - test rigs - universal characteristics - separation of losses - cavitation characteristics.

REFERENCES:

- Axial flow compressors - Velocity triangles - Blading - number and type of stagings - Air and blade angles - Degree of reaction - Losses - Radial equilibrium and actuator disc theory performance characteristics.

- Steam turbines - Types - Classification - constructional details of different types of steam turbines.

- Gas turbines - Types - Classification - Gas turbines engine and its components - constructional details of components - working principles of different components.

- Power Cycles - Basic steam and gas turbine power cycles - Analysis - Efficiencies - Thermodynamic methods of improving the cycle efficiencies - Heat rate and steam rate calculations.

- Axial flow turbines (Impulse and Reaction) - Velocity triangles -
- Turbine speed - Number of stages and stage work - Gas angles and blade angles.

- Losses in turbines - Reheat factor and condition curve - constant stage efficiency - forms of actual condition curve - Turbine total wheel speed.
- Gas turbine combustion chambers - Requirements - Flame stabilization - combustion efficiency - fuel injection and atomization - Different types of combustors.
- Gas turbine power plant matching characteristics.

REFERENCES:

• **Review of Governing Equations Fluid Flow and Heat Transfer**

• **Finite Difference, Discretization, Consistency, Stability and Fundamental of Fluid Flow Modeling.**

• **Solution of Viscous Incompressible Flows by Stream Function - Vorticity Formulation**
  Two Dimensional Incompressible Viscous Flow, Incorporation of Upwind Scheme, Estimation of Discretization Error, Application to Curvilinear Geometries, Derivation of Surface Pressure and Drag.

• **Solution of Navier-Stokes Equations for Incompressible Flows Using MAC and SIMPLE Algorithms**

• **Introduction to FVM: Integral Approach, discretization & Higher order scheme**

Reference:
• Design of compressors - Centrifugal compressor - Inlet section - Impeller passages - Effect of impeller blade shape on performance - Impeller channel - Vaneless and vaned diffusers - Effect of Mach number - Design procedure.

• Axial flow compressor - stage characteristics - Blading efficiency - Design parameters - Blade loading - Lift coefficient and solidity - Three dimensional flow considerations - Radial equilibrium design approach - Actuator disc theory approach - Design procedure and calculations.

• Design of Turbine flow passages - Introduction - Isentropic Velocity ratio - Energy distribution in turbines - Effect of carryover velocity on energy distribution.


• Reaction turbine flow passages - Reaction blade profiles - Blade angles - Gauging and pitch - Blade width and height - Losses in reaction blade passages - Degree of reaction - design procedure for impulse - reaction turbines - Calculations for axial thrust - Turbines for optimum capacity.

• Flow passage with radial equilibrium - The free vortex turbine - Turbine with constant specific mass flow - Turbines with constant nozzle angle - comparison of radial equilibrium design - off design performance using radial equilibrium theory - Actuator disc theory - Single parameter analysis - Stream line curvature methods - Discussion.

REFERENCES:

7. Frank P. Beleier, “Fan Hand Book Selection, Application and Design”
• Design of centrifugal pumps - selection of speed - determination of impeller inlet and outlet dimensions - meridional geometry inlet and exit blade angles - blade geometry - mixed flow pumps - elementary pump - design of twisted blade - design of volute - vaned diffuser and return passage - suction spiral -

• Axial flow pumps - selection of speed - pump casing geometry hub diameter - number of blades and cascade solidity - selection of blade geometry on different flow surfaces - diffuser design.

• Introduction to hydraulic turbine design - Type series and diameter series - selection of type and diameter - Reaction turbine runner spaces - meridional velocity field - elementary turbines - Hydraulic design of Francis turbine - Choice of basic parameters - Inlet and Outlet edges of runner blade - blade profiles on flow surfaces - shape of blade duct-velocity diagrams on different flow surfaces - certain guide lines to finalise the runner design - Guide wheel - Vane geometry and torque on controlling mechanism - Discharge and circulation - spiral - speed ring - draft tube.

• Hydraulic design of axial turbine runners - characteristics of some aerofoils - meridional flow field - blade geometry on each flow surface - procedure to finalize the runner design.

• Hydraulic design of pelton wheel - number of nozzles and their diameter - runner diameter - number of buckets - positioning of buckets - bucket geometry and size -- needle regulator - deflector.

REFERENCES:
Introduction to Heat Exchangers and classification
Basic Design Methodologies, -NTU Method AND lmtd method
Design of Double Pipe Heat Exchangers
Shell & Tube Type Heat Exchangers, TEMA, Nomenclature, j -Factors
Conventional Design Methods, Bell-Delware Method
Compact Heat Exchangers, j -Factors, Design Method
Condensers Classification and Design Methods for Surface Condensers
Evaporators – classification and Design Methods
Plate Type – Heat Exchangers
Regenerators
Basic Concepts of Mechanical Design of Heat Exchanger
Fixed and Floating Tube Sheet Design, Design of Expansion Bellows

Reference:
3. Longmann Scientific and Technical, N.Y., 1988
Programme Outcomes (POs)

Following are the programme outcomes for M.Tech. (Turbomachines) by the time the student attains post graduation:

(a) TECHNICAL COMPETENCE in the area of rotodynamic machines: This means the student will be equipped with the fundamental knowledge of principle of operation, component details and performance evaluation of these machines.

(b) RESEARCH APTITUDE: This means the students will be equipped with hard and soft skills required to carry out research and development in the area of rotodynamic machine

(c) CREATIVITY: This means the student should be able to generate his own ideas and concepts for design, develop and solving industrial issues related to turbomachines.

(d) ACADEMIC APTITUDE: This means the student should be able to comprehend the concepts and develop academic skills to disseminate his knowledge (or teach) to his others.

(e) APTITUDE TO USE MODERN TOOLS: This means the student must be able to apply modern and appropriate prediction and modeling tools to enhance his concepts and carry out research in the area of turbomachinery.
(f) **INDIVIDUAL AND TEAM WORK:** This means the student must possess an ability to work effectively as an individual and as a member or leader of the team.

(g) **MANAGERIAL RESPONSIBILITY:** This means student will be effective in handling managerial responsibilities along with technical responsibility.

(h) **SOCIO-ECONOMIC RESPONSIBILITY:** Student will be able to use his technical skills in Turbomachines for solving social economic problems and challenges.

(i) **PROFESSIONAL ETHICS:** This means the student must be effective in handling technical and managerial responsibilities related to his profession with high moral and ethical values.

(j) **LIFE-LONG LEARNING:** This means the student must be able to engage in independent and life-long learning in specialized technology of rotodynamic machines as well as on contemporary issues.

(k) **COMMUNICATION:** This means the student must be able to communicate verbally, in writing to others and explain his ideas effectively.

In order to attain the above described programme outcomes, detailed curriculum of the programme is designed. Courses offered under the programme have their own specific outcomes.

The course outcomes in brief are enlisted in the table shown below.