

DESIGN OF HYDROPOWER SYSTEMS

ENME 425

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to design and analyze the major hydro-mechanical components of hydropower systems. It covers intake structures, gates, penstocks, valves, trash racks, turbines, sediment handling systems and auxiliary mechanical systems. Emphasis is given to practical design, standards and case studies from real hydropower projects.

1 Introduction (4 hours)

- 1.1 Role of hydromechanical components in hydropower
- 1.2 Other components
 - 1.2.1 Intake structures
 - 1.2.2 Water conveyance system
 - 1.2.3 Control structures
- 1.3 Head losses in pipes and open channels
- 1.4 Design standards and codes
 - 1.4.1 IEC standards for hydropower
 - 1.4.2 ASME codes for pressure vessels
 - 1.4.3 IS codes and guidelines
 - 1.4.4 Safety regulations

2 Intake Structures and Trash Racks (6 hours)

- 2.1 Types of intakes (Surface, submerged, side intake)
- 2.2 Hydraulic design criteria
- 2.3 Trash rack design
 - 2.3.1 Bar spacing, head loss
 - 2.3.2 Structural design
- 2.4 Trash rack cleaning systems (Manual and mechanical)
- 2.5 Ice and debris control

3 Gates and Hoisting Equipment (7 hours)

- 3.1 Types of gates
 - 3.1.1 Vertical lift gate
 - 3.1.2 Radial gate
 - 3.1.3 Sluice gate

- 3.1.4 Stoplogs
- 3.1.5 Bulkhead gates
- 3.2 Hydraulic forces on gates
- 3.3 Sealing systems
- 3.4 Hoisting systems
 - 3.4.1 Rope drum hoist
 - 3.4.2 Hydraulic hoist
 - 3.4.3 Screw spindle
 - 3.4.4 Cranes and types
 - 3.4.5 Design of hoisting capacity and safety factors

4 Penstocks and Pressure Shaft design (10 hours)

- 4.1 Steel grades and properties
- 4.2 Air vent pipe and drain pipes
- 4.3 Types: Buried, exposed, tunnel, shaft
- 4.4 Hydraulic design: Diameter optimization; Head loss calculation
- 4.5 Structural design: Internal pressure; Water hammer effects; External pressure in vertical shaft
- 4.6 Anchor blocks and saddle supports
- 4.7 Expansion joints and supports

5 Valves and Control Systems (6 hours)

- 5.1 Types of valves
 - 5.1.1 Butterfly valve
 - 5.1.2 Spherical valve
 - 5.1.3 Needle valve
- 5.2 Selection criteria
- 5.3 Hydraulic and structural design considerations
- 5.4 Operation and control systems

6 Sediment Handling and Flushing Systems (6 hours)

- 6.1 Sediment problems in hydropower
- 6.2 Desanders and settling basins
- 6.3 Flushing systems
 - 6.3.1 Bottom outlets
 - 6.3.2 Flushing gates
- 6.4 Abrasion effects and mitigation

7 Turbine design and selection (6 hours)

- 7.1 Turbine design procedure
- 7.2 Characteristic curves of turbines
- 7.3 Selection of turbine

- 7.4 Deciding the number of turbine units, installation position, material and their manufacturing
- 7.5 Draft tube design

Tutorial

(30 hours)

1. Calculating head losses in intake structures and water conveyance systems
2. Designing trash rack bar profiles and determining spacing to optimize structural integrity and hydraulic efficiency
3. Computing hydrostatic and hydrodynamic forces on vertical lift and radial gates to determine hoisting capacity requirements
4. Optimizing penstock diameter and determining wall thickness by analyzing internal pressure and water hammer effects
5. Analyzing the stability of anchor blocks and saddle supports against longitudinal and lateral forces
6. Evaluating selection criteria for butterfly, spherical and needle valves based on specific site head and discharge
7. Sizing turbine units and designing draft tube dimensions using specific speed and characteristic curves
8. Designing sediment flushing systems and settling basins to mitigate abrasion in hydromechanical components

Practical

(15 hours)

1. Performing a comprehensive design review of hydromechanical installations at an operational hydropower plant
2. Utilizing specialized design software to simulate pressure surges and hydraulic transients in pressure shafts
3. Developing detailed 2D and 3D CAD drawings for gates, hoisting mechanisms and valve assemblies
4. Conducting a technical visit to a manufacturing facility to observe the fabrication and quality control of penstocks and turbines

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	4	6
2	6	8
3	7	8
4	10	14
5	6	8
6	6	8
7	6	8
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Gulliver, J. S., Arndt, R. E. A. (1991). Hydropower engineering handbook (Latest Edition). McGraw-Hill.
2. Novak, P., Moffat, A. I. B., Nalluri, C., Narayanan, R. (2017). Hydraulic structures (includes hydropower-related content). CRC Press.
3. Sharma, K. K. (2010). Mechanical equipment of hydropower plants. S. Chand Publishing.
4. International Electrotechnical Commission. (2019). IEC 61116: Electro-mechanical equipment for hydropower plants. IEC.
5. American Society of Mechanical Engineers. (2023). ASME boiler and pressure vessel code. ASME.
6. American Society of Mechanical Engineers. (2023). ASME codes for pressure vessels and pipelines. ASME.
7. Subramanya, K. (2017). Fluid mechanics and hydraulic machines. McGraw-Hill Education.
8. U.S. Bureau of Reclamation, American Society of Civil Engineers. (2010). Steel penstocks. ASCE.

ENERGY AUDIT OF ELECTRO-MECHANICAL SYSTEMS

ENME 426

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide knowledge regarding the energy efficiency improvement opportunities in electro-mechanical equipment. The course covers various methods of energy auditing techniques and energy efficiency management delivered through the lectures, practical demonstrations and on the site case studies. After completion of the course, students will be able to use knowledge and hands on experience and skills about energy auditing and managing the energy demand of electro-mechanical equipment.

1 Mechanical Energy Utility Systems

(18 hours)

- 1.1 Compressed air system
 - 1.1.1 Types of air compressors
 - 1.1.2 Compressors efficiency
 - 1.1.3 Efficient compressors operation
 - 1.1.4 Selection of compressor
 - 1.1.5 Compressed air system components
 - 1.1.6 Capacity assessment and leakage test
 - 1.1.7 Factors affecting the performance
 - 1.1.8 Energy saving opportunities
- 1.2 HVAC and Refrigeration
 - 1.2.1 Types of refrigeration system
 - 1.2.2 Common refrigerants and properties
 - 1.2.3 Selection of a suitable refrigeration system
 - 1.2.4 Performance assessment of refrigeration plants
 - 1.2.5 Ice bank system
 - 1.2.6 Cold storage system factors affecting performance and energy efficiency of refrigeration plants
 - 1.2.7 Energy savings opportunities
- 1.3 Fans and blowers
 - 1.3.1 Types, fan selection criteria and performance evaluation
 - 1.3.2 Efficient system operation
 - 1.3.3 Flow control strategies
 - 1.3.4 Duty cycle and life cycle cost
 - 1.3.5 Energy saving opportunities

- 1.4 Pumps and pumping systems
 - 1.4.1 Types, selection criteria and performance evaluation
 - 1.4.2 Efficient system operation
 - 1.4.3 Flow control strategies
 - 1.4.4 Oversizing of pump
 - 1.4.5 Impeller trimming
 - 1.4.6 Variable speed drives
 - 1.4.7 Energy conservation opportunities
- 1.5 Cooling towers
 - 1.5.1 Types and performance evaluation
 - 1.5.2 Efficient system operations
 - 1.5.3 Flow control strategies
 - 1.5.4 Assessment of saving opportunities
- 1.6 Diesel generating systems
 - 1.6.1 Factors affecting selection
 - 1.6.2 Energy performance assessment
 - 1.6.3 Energy savings measures

2 Electrical Energy Systems

(13 hours)

- 2.1 Electrical energy demand analysis
 - 2.1.1 Types of electrical loads in industrial and commercial facilities
 - 2.1.2 Building energy index, load profiling, energy demand analysis and forecasting
- 2.2 Energy tariff analysis
 - 2.2.1 Electricity tariff structures
 - 2.2.2 Demand charges tariff optimization strategies
- 2.3 Power factor management
 - 2.3.1 Causes and effects of low power factor
 - 2.3.2 Power factor improvement methods
 - 2.3.3 Harmonics and power quality considerations
- 2.4 Distribution losses in industrial systems
 - 2.4.1 Technical and non-technical losses
 - 2.4.2 Loss estimation methods
 - 2.4.3 Loss reduction techniques in LT and HT systems
 - 2.4.4 Trouble shooting of electrical power systems
- 2.5 Energy conservation in lighting systems
 - 2.5.1 Lighting technologies and efficiency comparison
 - 2.5.2 Lighting level standards and lux measurement
 - 2.5.3 Energy demand analysis in lighting
 - 2.5.4 Lighting retrofit strategies and controls
- 2.6 Energy conservation in motors and transformers
 - 2.6.1 Energy efficient motors, motor loading and efficiency assessment
 - 2.6.2 Motor selection criteria
 - 2.6.3 Rewinding vs replacement of motors
 - 2.6.4 Variable Frequency Drives (VFDs) and soft starters

- 2.6.5 Transformer efficiency and loading
- 2.6.6 Energy saving opportunities in transformer
- 2.7 Demand Side Management (DSM): Load shifting, peak shaving, valley filling, demand response programs and energy storage integration

3 Energy Conservation using Renewable Energy Technologies (5 hours)

- 3.1 Solar energy applications
 - 3.1.1 Solar water heating and process heating
 - 3.1.2 Solar PV for daytime peak load reduction system
 - 3.1.3 Net-metering and self-consumption strategies
 - 3.1.4 Sizing and performance estimation
- 3.2 Waste to energy technologies
 - 3.2.1 Biogas, biomass and industrial waste utilization
 - 3.2.2 Biomass gasifiers and boilers
 - 3.2.3 Industrial waste heat utilization and waste fuel recovery
 - 3.2.4 Economic and environmental benefits

4 Costing and Financial Analysis (4 hours)

- 4.1 Costing of energy efficiency measures: Capital and operational cost estimation; Life cycle cost analysis (LCCA); Risk and sensitivity analysis
- 4.2 Financial evaluation techniques

5 Case Study and Audit Report Preparation (5 hours)

- 5.1 Methodology for preliminary and detailed energy audit of electro- mechanical components
- 5.2 Energy flow diagram
- 5.3 Measuring instruments
- 5.4 Checklist for energy auditors
- 5.5 Energy audit report writing for selected case study site

Tutorial (30 hours)

- 1. Case study of compressed air system performance evaluation
- 2. HVAC and refrigeration load and performance calculations
- 3. Fans and blowers' performance analysis
- 4. Pump and pumping system analysis
- 5. Energy savings using variable speed drives (VSDs) (Energy saving estimation for pumps and fans using speed control strategies)
- 6. Thermal performance evaluation of cooling tower and diesel generator
- 7. Electrical tariff and electricity bill analysis
- 8. Power factor correction and transformer performance
- 9. Lighting and motor energy audit calculations
- 10. Solar PV system sizing and net-metering analysis (Daytime load matching, self-consumption estimation, export energy calculation and annual energy savings)

11. Comprehensive financial analysis of energy conservation measures
12. Energy audit methodology and checklist development

Practical

(15 hours)

1. Familiarization with energy audit measuring instruments for electro-mechanical equipment
2. Compressed air system performance test
3. Electrical energy audit using power analyzer
4. Motor and pump performance test
5. Lighting energy audit (Lux measurement, lighting power density and retrofit saving estimation)
6. Refrigeration or air conditioning system performance test

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	18	25
2	13	20
3	5	5
4	4	5
5	5	5
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Gottschalk, C. M. (1996). Industrial energy conservation (Latest Edition). John Wiley & Sons.
2. O'Callaghan, P. W. (1993). Energy management (Latest Edition). McGraw-Hill Book Company.
3. Thumann, A., Niehus, T., Younger, W. J. (2020). Handbook of energy audits. CRC Press.

REFRIGERATION SYSTEM DESIGN

ENME 427

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide the concept of simple and advanced refrigeration systems and the working principle of various types of refrigeration systems, cryogenics, various systems of cryogenics. After the completion of this course, students will be able to analyze the merits and demerits of various types of refrigeration systems and to design cold storage.

- 1 Introduction (4 hours)**
 - 1.1 Purpose and scope of refrigeration
 - 1.2 Classification of refrigeration systems
 - 1.3 Basic components of refrigeration systems
 - 1.4 Review of thermodynamic principles of refrigeration
 - 1.5 Performance parameters: COP, refrigeration capacity, compressor work

- 2 Refrigeration Cycles and System Performance (6 hours)**
 - 2.1 Vapor compression refrigeration cycle
 - 2.2 Pressure-enthalpy (P-h) diagram analysis
 - 2.3 Actual refrigeration cycle and system losses
 - 2.4 Multi-stage and refrigeration systems
 - 2.5 Cascade refrigeration systems
 - 2.6 Performance evaluation of refrigeration systems
 - 2.7 Concepts of vapor absorption and vapor jet refrigeration systems

- 3 Refrigerants and Environmental Considerations (7 hours)**
 - 3.1 Classification and properties of refrigerants
 - 3.2 Environmental impacts: ODP and GWP
 - 3.3 Natural refrigerants (Ammonia, CO₂, hydrocarbons)
 - 3.4 Criteria for refrigerant selection
 - 3.5 Global protocols and refrigerant phasedown schedules
 - 3.6 Refrigerant safety (ASHRAE 34) and lubricant compatibility
 - 3.7 Recovery, recycling and reclamation (RRR) of refrigerants

4 Refrigeration System Components and Equipment Selection (8 hours)

- 4.1 Compressors: Types and selection
- 4.2 Condensers: Air-cooled and water-cooled
- 4.3 Evaporators: Types and design considerations
- 4.4 Expansion devices: Capillary tube and thermostatic expansion valve
- 4.5 Auxiliary components: Receivers, accumulators, filters and driers
- 4.6 System balancing and matching of components

5 Low Temperature Refrigeration and Applications (8 hours)

- 5.1 Principles of low-temperature refrigeration
- 5.2 Cryogenic refrigeration systems
- 5.3 Cooling by adiabatic demagnetization
- 5.4 Applications of refrigeration: Food preservation, pharmaceuticals and industrial processes
- 5.5 Cryogenic refrigeration systems
- 5.6 Insulation technology: Vacuum insulation and multi-layer insulation (MLI)

6 Cold Storage Design and Cooling Load Calculation (12 hours)

- 6.1 Introduction to cold storage systems
- 6.2 Types of cold storage and suitability of occupying products
- 6.3 Product load calculations of agricultural products
- 6.4 Heat gain through walls, ceilings and floors
- 6.5 Air infiltration load
- 6.6 Internal loads: Lighting, motors, personnel
- 6.7 Total cooling load calculation for cold storage systems

Tutorial (30 hours)

1. Calculation of COP, refrigeration effect and compressor work from given data
2. Determination of thermophysical properties using table/software
3. Power consumption and efficiency calculation of refrigeration system while using Pressure-enthalpy (P-h) diagram
4. Design of a small cold storage system
5. Thermal analysis of cold storage using CFD tools
6. Calculation of pressure drop and determination of flow characteristics in refrigerant piping

Practical (15 hours)

1. Analysis of simple vapor compression refrigeration system
2. Investigation on effect of various conditions on COP
3. Leak detection, evacuation and charging of refrigerant
4. Calibration of thermometers and pressure gauges used in refrigeration labs
5. Field study of cold rooms (Cold storage) for vegetables and meat products
6. Case study of thermal performance of refrigeration units of dairy industry

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapter	Hours	Marks distribution*
1	4	6
2	6	10
3	7	10
4	8	10
5	8	10
6	12	14
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Arora, S. C., Domkundwar, S. (2018). A course in refrigeration and air conditioning. Dhanpat Rai & Co.
2. ASHRAE. (2022). ASHRAE handbook: Refrigeration. ASHRAE.
3. Boast, M. (2013). Newnes refrigeration pocket book. Elsevier.
4. Dossat, R. J., Horan, T. J. (2001). Principles of refrigeration. John Wiley & Sons.
5. Mathur, S. B., Domkundwar, S. (2016). Elements of mechanical engineering. Dhanpat Rai & Co.
6. Rajput, R. K. (2017). A textbook of refrigeration and air conditioning. Katson Books.
7. Stoecker, W. F., Jones, J. W. (1982). Refrigeration and air conditioning. McGraw-Hill Education.

FUNDAMENTAL OF ROBOTICS

ENME 428

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to introduce the fundamental concepts, components and classifications of robotic systems while developing a comprehensive understanding of kinematics, motion description and trajectory planning. Students will learn to analyze robot dynamics and gain familiarity with sensors, sensing systems and their integration into practical applications

1 Introduction (5 hours)

- 1.1 Classification of robots
- 1.2 Laws of robotics
- 1.3 History of robotics
- 1.4 Robot architecture
- 1.5 Joints, links, degree of freedom, coordinate system, work envelope
- 1.6 Robot configurations
- 1.7 Application: Industrial robot, space robot, exoskeleton, humanoid

2 Motion Description (6 hours)

- 2.1 Motion representation in 3D space
- 2.2 Position of a point
- 2.3 Orientation of a rigid body
- 2.4 Homogeneous transformation
- 2.5 Denavit and Hartenberg (D-H) parameters

3 Robot Kinematics (10 hours)

- 3.1 Introduction to robot kinematics
- 3.2 Serial and parallel robots
- 3.3 Forward kinematics
 - 3.3.1 Concept and basics
 - 3.3.2 Position and orientation
 - 3.3.3 D-H representation
 - 3.3.4 3R robotic arm and SCARA robot
- 3.4 Inverse kinematics
 - 3.4.1 Concept and basics
 - 3.4.2 RR planar manipulator, 3R robotic arm

- 3.5 Jacobian matrix
- 3.6 Dexterity and redundancy in robots

4 Trajectory Planning (6 hours)

- 4.1 Path and trajectory
- 4.2 Joint space planning
 - 4.2.1 Joint space representation
 - 4.2.2 Polynomial trajectories
 - 4.2.3 Position, velocity and acceleration profiles
- 4.3 Cartesian space trajectories
- 4.4 Path primitives
- 4.5 Point-to-point versus continuous path planning
- 4.6 Autonomous motion basics: Navigation and obstacle avoidance

5 Dynamics and Force Analysis (8 hours)

- 5.1 Forces and moments
- 5.2 Joint torques
- 5.3 Functional requirement of a robot
- 5.4 Inertia properties
- 5.5 Euler-Lagrange formulation
- 5.6 Newton-Euler formulation

6 Robot Drives and End Effector (4 hours)

- 6.1 Robot drive systems
 - 6.1.1 Electric drive
 - 6.1.2 Hydraulic drive
 - 6.1.3 Pneumatic drive
- 6.2 End effector
 - 6.2.1 Introduction and classification
 - 6.2.2 Gripper: Mechanical, vacuum and magnetic
 - 6.2.3 Gripper design basics
 - 6.2.4 Robot hand

7 Sensors and Sensing Systems (6 hours)

- 7.1 Sensor classification: Proprioceptive and exteroceptive
- 7.2 Haptic sensors: Introduction, types, working
- 7.3 Torque sensors
- 7.4 Navigation and range sensors
- 7.5 Position sensors and encoders
- 7.6 Vision systems
 - 7.6.1 Machine Vision

- 7.6.2 Image acquisition and processing
- 7.6.3 Obstacle detection and recognition

Tutorial

(30 hours)

1. Configuration and motion representation of robot Structure
2. Analysis of Robot kinematics: Forward and inverse solutions
3. Trajectory planning in robotic systems
4. Modeling of robot dynamics and force analysis
5. Sensor integration, robot drives and end effector design

Practical

(15 hours)

1. Robot workspace visualization and motion representation
2. Forward and inverse kinematics simulation of serial manipulators
3. Trajectory planning using MATLAB/Python
4. Raspberry Pi based sensor integration for robotic applications
5. Exercises related to ROS programming

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1, 2	11	14
3	10	14
4	6	8
5	8	10
6	4	6
7	6	8
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Craig, J. J. (2009). Introduction to robotics: Mechanics and control. Pearson.
2. Saha, S. K. (2014). Introduction to robotics. McGraw-Hill Education.
3. Niku, S. B. (2020). Introduction to robotics: Analysis, control, applications. John Wiley & Sons.
4. Taghirad, H. D. (2025). Fundamentals of robotics: Applied case studies with MATLAB® and Python. CRC Press.
5. Klatfeter, R. D., Chmielewski, T. A., Negin, M. (2006). Robotic engineering: An integrated approach. Prentice Hall.

CONSTRUCTION EQUIPMENT

ENME 429

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide students with a comprehensive understanding of the types, operation, management, repair, and maintenance of heavy equipment used in construction and agriculture. Upon completion, students will be able to identify and classify various equipment, diagnose common operational problems, apply appropriate maintenance and repair procedures, and implement effective equipment management practices to ensure safety, reliability, and operational efficiency.

1 Introduction to Hydraulic system (6 hours)

- 1.1 Basic principle of hydraulics
- 1.2 Elements of hydraulic system: Hydraulic power pack, control valve and actuators
- 1.3 Types of hydraulic system: Open center system, closed center system
- 1.4 Hydraulic oil: Functions, storage, types, properties, specifications and requirements
- 1.5 Pumps: Types and working principle
- 1.6 Valves: Types and working principle
- 1.7 Actuators: Purpose, types and working principle
- 1.8 Auxiliaries: Accumulator, filter, reservoir, oil cooler, hose pipe, tubes and couplers, seals and fluids

2 Pneumatic System (3 hours)

- 2.1 Basic principle of pneumatics
- 2.2 Compressed air: Functions, properties and preparation
- 2.3 Elements of pneumatic system: Compressor, control valve and actuators
- 2.4 Compressor: Types and working principle
- 2.5 Valves: Types and working principle
- 2.6 Actuators: Purpose, types and working principle
- 2.7 Auxiliaries: Accumulator, filter, lubricator, air cooler, receiver, pipe

3 Introduction to Heavy Equipment (9 hours)

- 3.1 Introduction
- 3.2 Classification of heavy equipment based on: Applications, truck type, crawl and wheel type

- 3.3 Application of heavy equipment
- 3.4 Terminologies used in heavy equipment
- 3.5 Construction equipment: Introduction, construction, types, applications and general specifications of dozer, loader, excavator, grader, road roller, asphalt paving equipment, crane
- 3.6 Farm tractor: Layout, different types of implements, accessories and attachments, tractor trolley
- 3.7 Special purpose vehicles: Fork lift, fire brigade, dumper, tripper, truck

4 Chassis Components (9 hours)

- 4.1 Hydraulic system
- 4.2 Transmission system: Clutches, mechanical transmission, hydraulic assist transmission, power shift transmission, hydrostatic drive, torque converters, differential, final drive, power take-offs, special drives
- 4.3 Undercarriage: Track chain, idler, sprocket, track rollers, tyres
- 4.4 Implements and tools: Blades, rippers, bucket

5 Electronic Components (3 hours)

- 5.1 Functions and symbols of pressure sensor
- 5.2 Working of pressure switch
- 5.3 Mechanism of proportional solenoid, pump and valve controller
- 5.4 Working and purpose of engine controller

6 Hydraulic and Pneumatic Circuit (6 hours)

- 6.1 Pneumatic circuits: Basic pneumatic circuit, impulse operation, speed control, pneumatic motor circuit, sequencing of motion, time delay circuits and their applications
- 6.2 Hydraulic circuit: Basic hydraulic circuit, impulse operation, speed control, hydraulic motor circuit, sequencing of motion, time delay circuits and their applications
- 6.3 Maintenance and troubleshooting of hydraulic and pneumatic system

7 Management of Heavy Equipment (9 hours)

- 7.1 Safety inspections
- 7.2 Special care and precautions
- 7.3 Equipment policy
 - 7.3.1 Equipment acquisition: Methods purchase, leasing, hiring
 - 7.3.2 Comparison between leasing and purchasing
 - 7.3.3 Estimation of owning and operating cost and hiring cost
 - 7.3.4 Analysis of equipment utilization and price variance

7.4 Equipment procurement

7.4.1 Marketing aspects of construction equipment (Availability, dealers)

7.4.2 Procurement methods and practices

7.4.3 Commissioning of equipment

Tutorial

(30 hours)

1. Analysis of owning and operating cost of construction equipment
2. Detailed comparison of leasing, hiring and purchasing cost of construction equipment
3. Analysis of equipment utilization, productivity and idle time cost
4. Detailed analysis of procurement process, commissioning and profitability of construction equipment operation

Practical

(15 hours)

1. Demonstration of hydraulic system
2. Demonstration of pneumatic system
3. Familiarization with hydraulic assisted transmission system
4. Assignments on procurement of heavy equipment
5. Repair and maintenance of heavy equipment

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1, 2	9	12
3	9	12
4	9	12
5, 6	9	12
7	9	12
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Caterpillar Inc. (2002). Caterpillar performance handbook. Caterpillar Inc.
2. Harris, F., McCaffer, R. (1982). Construction plant: Excavating and material handling, equipment and methods (Latest Edition). Granada Publishing.
3. Harris, F., McCaffer, R. (2013). Management of construction equipment. Macmillan Education.
4. SAE International. SAE handbook. SAE International.
5. Schulz, E. J. (1982). Diesel equipment I and II (Latest Edition). McGraw-Hill Education.

QUALITY MANAGEMENT

ENME 430

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide fundamental and advanced knowledge of quality management principles, tools, and techniques for improving product and process performance in mechanical engineering applications. It also aims to develop competency in applying modern quality approaches such as TQM, lean, and six sigma in industrial systems.

- 1 Introduction (3 hours)**
 - 1.1 Definition and dimensions of quality
 - 1.2 Evolution of quality concepts
 - 1.3 Contributions of Deming, Juran, Crosby
 - 1.4 Quality in manufacturing and service industries
 - 1.5 National and international quality standards (Including Nepal standards)

- 2 Total Quality Management (TQM) (5 hours)**
 - 2.1 Concept, principles and philosophy of TQM
 - 2.2 Customer focus and continuous improvement (Kaizen)
 - 2.3 Leadership, teamwork and employee involvement
 - 2.4 Organizational culture and quality transformation
 - 2.5 TQM implementation framework and barriers

- 3 Cost of Quality and Performance Measurement (4 hours)**
 - 3.1 Cost of quality (Prevention, Appraisal, Failure)
 - 3.2 Economics of quality
 - 3.3 Performance measurement and key indicators
 - 3.4 Benchmarking techniques

- 4 Quality Systems and Standards (5 hours)**
 - 4.1 Quality management system (QMS)
 - 4.2 ISO 9001 requirements and structure
 - 4.3 Documentation and auditing practices
 - 4.4 Certification and accreditation procedures
 - 4.5 Integration with ISO 14001 and ISO 45001

5	Process Quality and Reliability	(5 hours)
5.1	Process variation and control	
5.2	Process capability indices	
5.3	Reliability concepts and failure analysis	
5.4	Maintainability and availability	
5.5	Applications in mechanical systems	
6	Inspection, Measurement and Metrology	(4 hours)
6.1	Inspection planning and methods	
6.2	Measurement systems and errors	
6.3	Gauge capability and calibration	
6.4	Basics of non-destructive testing (NDT)	
6.5	Role of metrology in quality assurance	
7	Statistical Quality Control (SQC) and SPC	(8 hours)
7.1	Basic statistical concepts for quality	
7.2	Control charts for variables and attributes	
7.3	Process control and improvement	
7.4	Process capability analysis	
7.5	Acceptance sampling	
7.6	Seven basic quality tools	
8	Advanced Quality Improvement Techniques	(5 hours)
8.1	Six sigma and DMAIC methodology	
8.2	Lean manufacturing principles	
8.3	Failure mode and effects analysis (FMEA)	
8.4	Design of experiments (DOE) basics	
8.5	Taguchi methods and loss function	
9	Total Productive Maintenance and Quality in Manufacturing	(6 hours)
9.1	Total productive maintenance (TPM) concepts and pillars	
9.2	Overall equipment effectiveness (OEE)	
9.3	Zero defect and zero breakdown philosophy	
9.4	Safety systems and risk assessment	
9.5	Industrial safety standards (ILO and national context)	
9.6	Quality in machining and production systems	
9.7	Automation and digital quality control	
9.8	Smart manufacturing and real-time monitoring	
9.9	AI and data analytics in quality management	
Tutorial		(30 hours)
1.	Numerical problems on SPC and process capability	
2.	Case studies on TQM, lean and six sigma	

3. ISO documentation and auditing exercises
4. Reliability and cost of quality analysis
5. Group discussions and presentations on quality management tools and techniques

Practical

(15 hours)

1. Construction and analysis of control charts using software
2. Process capability study using sample data
3. Measurement system analysis (MSA)
4. Mini-project on quality improvement
5. Industrial visit and report

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1, 2	8	11
3, 4	9	12
5, 6	9	12
7	8	11
8	5	7
9	6	7
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Montgomery, D. C. (2019). Introduction to statistical quality control. Wiley.
2. Evans, J. R., Lindsay, W. M. (2020). Managing for quality and performance excellence. Cengage Learning.
3. Besterfield, D. H. (2018). Quality control. Pearson.
4. Oakland, J. S. (2014). Total quality management and operational excellence. Routledge.
5. Pyzdek, T., Keller, P. (2018). The Six Sigma handbook. McGraw-Hill Education.
6. Juran, J. M., De Feo, J. A. (2017). Juran's quality handbook. McGraw-Hill Education.
7. Taguchi, G. (2005). Taguchi's quality engineering handbook. Wiley.

AIRCRAFT PROPULSION SYSTEMS

ENME 431

Lecture : 3
Tutorial : 2
Practical : 1

Year : IV
Part : I

Course Objectives:

The objective of this course is to provide concepts on thermodynamic cycles and fluid dynamic principles governing various aerospace propulsion systems. It also covers performance characteristics of air-breathing engines, including turbojets, turbofans and UAV-specific propulsion architectures.

1 Introduction (4 hours)

- 1.1 Classification of aircraft propulsion systems
- 1.2 Working principle of piston-propeller, turbojet, turbofan, turboprop and turboshaft engines
- 1.3 Fundamentals of ramjet; Scramjet and rocket engines
- 1.4 Engine components overview
- 1.5 Generic gas turbine layout: Intake/diffuser, compressor, combustor, turbine, nozzle

2 Thermodynamic Foundations of Gas Turbines (8 hours)

- 2.1 Gas turbine engine components
- 2.2 Theoretical and real gas turbine cycle (Brayton cycle)
- 2.3 Ideal Brayton cycle: Processes, T-S diagram
- 2.4 Cycle parameters affecting performance: Pressure ratio, turbine inlet temperature, specific work output, thermal efficiency
- 2.5 Real cycle considerations: Compressor, turbine and nozzle inefficiencies, combustion pressure loss
- 2.6 Cycle modifications with intercooling, re-heating and regeneration
- 2.7 Total (Stagnation) properties: Temperature and pressure; Isentropic flow properties

3 Performance Parameters (6 hours)

- 3.1 Momentum theory of thrust (Control volume approach)
- 3.2 Control volume idea for propulsion systems
- 3.3 Thrust equations and its significance
- 3.4 Pressure matching at nozzle

- 3.5 Engine performance parameters: Thrust specific fuel consumption (TSFC), specific impulse and equivalent jet velocity
- 3.6 Propulsive, thermal and overall efficiency

4 Intake, Combustion Chamber and Nozzle (9 hours)

- 4.1 Working principle of intake/diffuser
- 4.2 Subsonic and supersonic inlet
- 4.3 Functions and design requirements of combustion chamber
- 4.4 Types of combustion chambers
- 4.5 Combustion efficiency, pressure loss in combustor and flame stabilization
- 4.6 Principle and application of aircraft nozzles: Thrust vectoring, thrust reversal and noise control
- 4.7 Convergent, convergent-divergent, fixed and variable area nozzles
- 4.8 Comparison of bell nozzle and aerospike nozzle
- 4.9 Choked flow, under-expanded, over-expanded, perfectly-expanded jets
- 4.10 Shock and expansion waves, Mach diamonds

5 Compressor and Turbine (10 hours)

- 5.1 Compressor types: Axial and centrifugal compressors
- 5.2 Compressor instability: Stall and surge
- 5.3 Losses in compressor
- 5.4 Types of turbines
- 5.5 Types of turbine cooling
- 5.6 Turbine losses: Profile loss, tip clearance loss, secondary flow/end-wall loss, mechanical loss

6 UAV Propulsion (4 hours)

- 6.1 Overview of UAV propulsion system
- 6.2 Typical UAV propulsion options: Electric motor-propeller, small IC engine-propeller
- 6.3 Endurance versus payload versus speed trade-offs
- 6.4 Engine selection for drones, STOL aircraft and helicopters

7 Advanced Propulsion (4 hours)

- 7.1 Ramjet and scramjet: Operating principle, supersonic combustion
- 7.2 Key challenges: Mixing, ignition, thermal loads
- 7.3 Rocket propulsion: Solid versus liquid versus hybrid rockets
- 7.4 Aircraft-rocket comparison
- 7.5 Emerging propulsion concepts

Tutorial (30 hours)

- 1. Calculation of propulsive, thermal and overall efficiencies of aircraft propulsion systems and evaluation of thrust specific fuel consumption (TSFC)

2. Numerical analysis of ideal Brayton cycle for aircraft gas turbine engines, including cycle efficiency and network output
3. Performance evaluation of real gas turbine cycle considering compressor and turbine efficiencies, combustion pressure loss and turbine inlet temperature
4. Performance analysis of convergent and convergent-divergent nozzles, including nozzle efficiency and effect on thrust
5. UAV propulsion system estimation exercises, including power requirement, energy consumption and basic propeller/motor selection

Practical

(15 hours)

1. Modeling and analysis of jet engine components using 3D CAD software
2. Visualization and evaluation of nozzle airflow patterns and thrust generation
3. Simulation and testing of gas turbine cycles to measure engine performance
4. Calculation and assessment of key engine parameters using thermodynamic models
5. Performance matching of motors and propellers to optimize UAV flight requirements

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1	4	6
2	8	10
3	6	10
4	9	12
5	10	12
6, 7	8	10
Total	45	60

* There may be minor deviation in marks distribution.

References

1. Peng, W. W. (2008). Fundamentals of turbomachinery. John Wiley & Sons.
2. Farokhi, S. (2022). Aircraft propulsion: Cleaner, leaner and greener. John Wiley & Sons.
3. Kerrebrock, J. L. (1992). Aircraft engines and gas turbines (Latest Edition). MIT Press.
4. Ward, T. A. (2010). Aerospace propulsion systems. John Wiley & Sons.
5. Fahlstrom, P. G., Gleason, T. J., Sadraey, M. H., Belobaba, P., Cooper, J., & Seabridge, A. (2022). Introduction to UAV systems. John Wiley & Sons.
6. Haran, K., Madavan, N., O'Connell, T. C. (Eds.). (2021). Electrified aircraft propulsion: Powering the future of air transportation. Cambridge University Press.