Unit 5023: Thermofluids

Unit Code: R/651/0887

Level: 5

Credits: 15

Introduction

In everyday life, you are never too far away from some system or device that relies on both fluid mechanics and thermodynamics. From the water circulating in your home central heating radiators to the hydraulic door closer to the back of a fire door, the presence of thermofluids is constantly around us.

This unit aims to provide a rational understanding of functional thermodynamics and fluid mechanics in common industrial applications. The unit promotes a problem-based approach to solving realistic work-related quandaries such as steam plant efficiency and fluid flow capacities, and complements other units such as *Units 4011, 4013,* and *5005*.

Students will examine fundamental thermodynamic principles, steam and gas turbine systems, and viscosity in fluids, along with static and dynamic fluid systems. Each element of the unit will identify a variety of engineering challenges and assess how problems are overcome in real-life industrial situations.

Students will develop their perceptions of industrial thermodynamic systems, particularly those involving steam and gas turbine power. In addition, they will consider the impact of energy transfer in engineering applications along with the characteristics of fluid flow in piping systems and numerous hydraulic devices, all of which are prevalent in typical manufacturing and process facilities.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Evaluate industrial thermodynamic systems and their properties

LO2 Examine the operation of practical steam and gas turbine plants

LO3 Illustrate the effects of viscosity in fluids

LO4 Analyse fluid systems and hydraulic machines.

Essential Content

LO1 Evaluate industrial thermodynamic systems and their properties

Thermodynamic systems:

Power generation plant

Application of the first law of thermodynamics

Analysis of Non-Flow Energy Equation (NFEE) and Steady Flow Energy Equation (SFEE) systems

Application of thermodynamic property tables

Energy transfer systems employing polytropic processes (isothermal, adiabatic, and isentropic)

Pressure/volume diagrams and the concept of work done: use of conventions

The application of the Gas Laws and polytropic laws for vapours and gases

Heat transfer theory and fundamentals

One-dimensional conduction and thermal resistance

Application of problem-solving tools in the context of thermodynamic system investigations e.g. root cause analysis (RCA), process failure modes effects analysis (PFMEA), fishbone, practical problem solving (PPS), advanced product quality planning (APQP)

Health and safety within the context, including risk awareness and compliance.

LO2 Examine the operation of practical steam and gas turbine plants

Steam and gas turbine plant:

Second Law of Thermodynamics and entropy

Heat Engine, Heat pump, and Carnot cycle

Entropy property and T-s diagram

Principles of operation of steam and gas turbine plants

Use of property diagrams to analyse plant

Characteristics of steam/gas turbine plant as used in energy supply

Energy-saving options adopted on steam plants operating on modified Rankine cycle

Performance characteristics of steam and gas power plant

Cycle efficiencies: turbine isentropic efficiencies and overall relative efficiency

Use of various problem-solving tools in the context of steam and gas turbine plants, with industry scenarios and real-world case studies.

LO3 Illustrate the effects of viscosity in fluids

Viscosity in fluids:

Viscosity: shear stress, shear rate, dynamic viscosity, kinematic viscosity

Viscosity measurement: operating principles of viscosity measuring devices e.g., falling sphere, U-tube, rotational and orifice viscometers (such as Redwood)

Newtonian fluids and non-Newtonian fluids: pseudoplastic, Bingham plastic, Casson plastic, and dilatant fluids

Latest trends and applications of viscous fluids.

LO4 Analyse fluid systems and hydraulic machines

Fluid systems:

Characteristics of fluid flow: laminar and turbulent flow, Reynolds number

Friction factors: relative roughness of pipe, use of Moody diagrams

Head losses across various industrial pipe fittings and valves, use of Bernoulli's Equation and Darcy's Formula

External incompressible flow and boundary layer

Boundary layer development on a flat surface

Separation and Wake

Aerodynamic forces: lift and drag

Hydraulic machines:

Turbines: Pelton wheel, Kaplan turbine, Francis wheel

Pumps: centrifugal, reciprocating.

Analysis of systems:

Dimensional analysis: verification of equations for torque, power, and flow rate

Application of dimensional analysis to determine the characteristics of a scale model

Use of Buckingham Pi Theorem

Discussion of dimensionless numbers: Reynold, Mach, Froude, Prandtl, and Nusselt numbers.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Evaluate industrial thermodynamic systems and their properties		
P1 Evaluate the operation of industrial thermodynamic systems and their properties. **P2** Describe the application of the first law of thermodynamics to industrial systems. **P3** Apply first law analysis for a process of ideal gas.	**M1** Analyse the rate of heat transfer through a composite wall.	**D1** Critically evaluate thermodynamic processes by using non-flow energy equation (NFEE) or steady flow energy equation (SFEE) systems with thermodynamic property tables.
LO2 Examine the operation of practical steam and gas turbine plants		
P4 Examine the principles of operation of steam turbine plant. **P5** Calculate overall steam turbine plant efficiencies by the use of charts and/or tables. **P6** Discuss the principles of operation of gas turbine plants.	**M2** Justify why the Rankine cycle is preferred over the Carnot cycle in steam production plants around the world.	**D2** Evaluate the modifications made to the basic Rankine cycle to improve the overall efficiency of steam power plants.
LO3 Illustrate the effects of viscosity in fluids		
P7 Illustrate the properties of viscosity in fluids. **P8** Explore three viscosity measurement techniques.	**M3** Evaluate the effects of shear force on Newtonian and non-Newtonian fluids.	**D3** Compare the results of a viscosity test on a Newtonian fluid with those given on a data sheet and explain any discrepancies.
LO4 Analyse fluid systems and hydraulic machines		
P9 Analyse the characteristics of fluid flow in industrial piping systems. **P10** Discuss the operational aspects of hydraulic machines. **P11** Apply dimensional analysis to fluid flow.	**M4** Review the significance of the Reynolds number on fluid flow in a given system.	**D4** Evaluate the use of dimensionless analysis using the Buckingham Pi Theorem for a given industrial application.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Baskharone E. A. (2012) *Thermal Science: Essentials of Thermodynamics, Fluid Mechanics, and Heat Transfer*. McGraw Hill.

Bejan A. (2016) *Advanced Engineering Thermodynamics.* John Wiley & Sons, Inc.

Borgnakke C. and Sonntag R. (2022) *Fundamental of Thermodynamics.* 10h Ed. Wiley

Cengel Y. (2020) *Heat and Mass Transfer: Fundamentals and Applications*. 6th Ed. McGraw Hill.

Cengel Y. (2019) *Thermodynamics: An Engineering Approach Si*. 9th Ed. McGraw Hill.

Cengel Y.A. and Cimbala J.M. (2013) *Fluid Mechanics Fundamentals and Applications (Mechanical Engineering)* Hardcover. McGraw-Hill.

Massey B.S. and Ward-Smith J. (2011) *Mechanics of Fluids.* 9th Ed. Oxford: Spon Press.

Revankar S., Sen S. and Sahu D. (Editors) (2021) *Proceedings of International Conference on Thermofluids KIIT Thermo 2020*. Springer.

Trachenko K. (2023) *Theory of Liquids: From Excitations to Thermodynamics* (Hardback). Cambridge University Press.

White F. and Xu H. (2021) *Fluid Mechanics.* 9th Ed McGraw Hill.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Annual Review of Fluid Mechanics

Experimental Thermal and Fluid Science

International Journal of Thermofluids

International Journal of Thermofluid Science and Technology

ISME Journal of Thermofluids

Journal of Fluid Mechanics

International Journal of Heat and Fluid Flow

Journal of Fluids Engineering

Links

This unit links to the following related units:

Unit 4011: Fluid Mechanics

Unit 4013: Fundamentals of Thermodynamics and Heat Engines

Unit 4024: Electro, Pneumatic and Hydraulic Systems

Unit 5005: Further Thermodynamics.