Simscape Fluids for Fluid & Thermal System Modeling

1. Title

Simscape Fluids for Fluid & Thermal System Modeling

2. Target Audience

This course is designed for mechanical, aerospace, and fluid power engineering students, researchers, and practicing engineers who need to model, analyze, and simulate hydraulic, pneumatic, and thermal-liquid systems using MATLAB, Simulink, and Simscape Fluids. It suits learners with a working knowledge of MATLAB/Simulink who want to progress from hydraulic power system fundamentals through pump, valve, and actuator design to electrohydraulic servosystems, pneumatic systems, and thermal-liquid modeling. No prior Simscape Fluids experience is required, though familiarity with basic fluid mechanics and thermodynamics is helpful for interpreting the theoretical derivations.

3. Course Outcomes

- Understand the fundamentals of hydraulic power systems and hydraulic oil properties.
- Apply transmission line theory to model hydraulic pipelines and hoses.
- Analyze the performance characteristics of hydraulic pumps and control valves.
- Design and evaluate hydraulic actuators and hydraulic servo actuators.
- Create electrohydraulic servovalve models and analyze their dynamic behavior.
- Build and simulate complete electrohydraulic servosystems in MATLAB and Simscape Fluids.
- Implement pneumatic system models and analyze compressible-flow behavior.
- Model thermal-liquid systems, heat exchangers, and gas-cooling networks in Simscape Fluids.
- Evaluate simulation output to validate fluid and thermal system design assumptions.
- Troubleshoot common Simscape Fluids modeling issues (domain mismatches, solver convergence, block parameterization).

4. Course Objectives

- Provide a structured, progressive learning path from hydraulic power fundamentals to complete fluid and thermal system simulation.
- Build proficiency with both analytical (MATLAB) and simulation-based (Simscape Fluids) approaches to fluid power system analysis.

- Prepare learners to design, analyze, and validate real hydraulic, pneumatic, and thermal-liquid systems.
- Reinforce every concept through practical MATLAB and Simscape Fluids exercises paired directly with the theoretical background.
- Equip learners with the domain-specific toolbox knowledge (Simscape, Simscape Fluids) needed to build production-ready fluid and thermal models.

5. Course Outline

The course comprises 40 hours of theory and labs and is divided into 11 different chapters. Each chapter will be followed by hands-on lab exercises to reinforce learning and gauge understanding of the topics covered.

6. Table of Contents (TOC)

Module 1: Introduction to Hydraulic Power Systems

- Overview of hydraulic power system components and architecture
- Advantages and applications of fluid power across industries
- Basic hydraulic circuit configurations
- Energy transfer and efficiency in hydraulic systems
- Overview of the course's dual analytical/simulation approach (MATLAB + Simscape Fluids)

Module 2: Hydraulic Oils and Theoretical Background

- Physical and thermal properties of hydraulic oils (viscosity, bulk modulus, density)
- Effects of temperature and pressure on fluid behavior
- Fundamental fluid mechanics principles applied to hydraulic systems
- Fluid contamination and its effect on system performance
- Practical example: parameterizing thermal-liquid fluid properties in Simscape Fluids

Module 3: Hydraulic Transmission Lines

- Pressure loss and flow characteristics in pipelines and hoses
- Laminar vs. turbulent flow in transmission lines
- Modeling pipeline dynamics analytically in MATLAB
- Selecting and sizing hydraulic lines for system requirements
- Lab: modeling a hydraulic transmission line in Simscape Fluids

Module 4: Hydraulic Pumps

- Types of hydraulic pumps (gear, vane, piston) and their operating principles
- Pump performance characteristics and efficiency analysis
- Modeling pump flow and pressure output analytically
- Selecting pumps for specified system requirements

- Lab: modeling a hydraulic pump in Simscape Fluids

Module 5: Hydraulic Control Valves

- Types of control valves (directional, pressure, flow control)
- Valve flow characteristics and pressure-drop analysis
- Modeling valve dynamics analytically in MATLAB
- Selecting valves for specified control requirements
- Lab: modeling hydraulic control valves in Simscape Fluids

Module 6: Accessories

- Hydraulic accumulators, filters, and reservoirs
- Function and selection of hydraulic system accessories
- Impact of accessories on system performance and reliability
- Sizing accessories for specified system requirements
- Practical example: incorporating accessories into a hydraulic circuit model

Module 7: Hydraulic Actuators

- Types of hydraulic actuators (cylinders, motors) and their operating principles
- Actuator force, torque, and speed characteristics
- Modeling actuator dynamics analytically in MATLAB
- Selecting actuators for specified load and motion requirements
- Lab: modeling a hydraulic actuator in Simscape Fluids

Module 8: Hydraulic Servo Actuators

- Servo actuator configurations and operating principles
- Closed-loop control of hydraulic servo actuators
- Modeling servo actuator dynamics analytically in MATLAB
- Performance metrics for servo actuator systems
- Lab: modeling a hydraulic servo actuator in Simscape Fluids

Module 9: Electrohydraulic Servovalve Technology

- Electrohydraulic servovalve types and operating principles
- Servovalve dynamic response characteristics
- Modeling servovalve behavior analytically in MATLAB
- Selecting servovalves for specified control bandwidth requirements
- Practical example: characterizing a servovalve's frequency response

Module 10: Modeling and Simulation of Electrohydraulic Servosystems

- Integrating servovalves, actuators, and controllers into a complete servosystem
- Analytical modeling of closed-loop electrohydraulic servosystems in MATLAB
- Controller design considerations for servosystem stability and performance
- Comparing analytical and simulation-based servosystem results

- Lab: building and validating a complete electrohydraulic servosystem in Simscape Fluids

Module 11: Introduction to Pneumatic Systems and Thermal-Liquid Modeling

- Fundamentals of pneumatic system components and compressible flow
- Comparing pneumatic and hydraulic system design considerations
- Modeling thermal-liquid systems, heat exchangers, and gas-cooling networks in Simscape Fluids
- Exchanging heat between fluid domains in a multidomain model
- Capstone lab: building and validating a combined fluid and thermal system model in Simscape Fluids