Maha Fluid Power Research Center

Intensive Course on HYDRAULIC CONTROL SYSTEMS

Dates and location:

February 10 – 14, 2024 at Purdue University, West Lafayette, IN
The event is in person only and limited to 24 participants.

Target audience:

Industry professionals with STEM degree, with already basic knowledge and experience in hydraulic components. Suggested the class on Fundamentals in Industrial and Mobile Hydraulics offered by Maha.

Course Description

This course covers the fundamental principles of hydraulic control actuation. Focus will be given to mobile applications, although the class will also describe some concepts of hydraulic servo. **The class assumes the participants being already familiar with the basics of fluid power components such as pumps, motors, cylinder, hydraulic control valves, and accumulators**.
The course details the design and functioning of complete hydraulic control systems. The basic control concepts are described first, for the case of circuits controlling a single actuator; the case of multiple actuators is covered afterwards, as an extension of the single actuator control concepts. Emphasis is given to the challenge of meeting functional requirements of a given application, while minimizing cost of ownership as well as energy consumption. Starting from the basic circuits, the lectures and labs will also cover current state of art systems for mobile applications, covering constant pressure systems, open center systems, load sensing systems, hydrostatic transmissions.
The course includes class lectures (mornings) but also hands-one labs experiences (afternoons). Labs will be performed using Purdue's Hydraulic Trainers specifically designed to support fluid power education.
During the lab experiences, the participants will learn how to perform basic tests on components and systems, and how to analyze the functioning of system and their energy consumption.
One-hour tests (worked problem / quizzes) will be provided to all participants at the end of each day to assess the learning of class material.

Morning lectures - structure

The morning sessions are classroom style lectures. The instructor will present the contents using material previously provided to the participants (pdfs and paper copies). Additional explanations will be provided using classroom blackboard or similar tools. The class participants are not required to purchase additional material; however, proper references for further readings and detailed explanations will be provided for who interested in further independent study.
Typical structure of the morning lectures is as follow:

8:30am – 10:00am – theory
10:00am – 10:15am – break
10:15am – 12:30pm – theory, problems and solutions

Afternoon labs - structure

The afternoon labs are hands-on experiences related to the contents presented during the morning lectures. The labs are performed at the Parker Hannifin Fluid Power and Motion Control Lab of Purdue University (Agricultural and Biological Engineering Department). Participants will be divided in groups of max 4 people and will use the Hydraulic Trainer (Fig. 1 below) to perform each experience.
Each lab experience has a handout that will be provided to each participant. The handout presents the goals of each test and describes the basic procedure to follow to perform the tests. The handout also includes specific questions related to the tests that stimulate the participant's learning.

Schedule for the afternoon labs:

1:30pm – 3:30pm – lab session
3:30pm – 4:00pm – break

Figure 1 – *Hydraulic Trainers at the Purdue's Parker Hannifin Fluid Power and Motion Control lab*

Afternoon tests - structure

A test inclusive of quizzes and worked problems is provided every day to assess the comprehension of the material covered during the day.
Course completion certificate requires submitting all tests and performing with a score greater than 60/100. There is a total of four tests covering the material of Day 1 through Day 4. There is no test for the Day 5 (study cases).
Please note that the test will be kept confidential, the individual or overall test scores will not be shared to participants or employers.

Test schedule:
4:00pm – 5:00pm

Specific Learning Outcomes

After completion of the course, the participant will be capable of (course learning objectives):

CL 1. Describe the operation, represent with proper symbology, the control and the energy consumption features of the hydraulic architectures available for controlling single and multiple actuators:

primary controlled system, metering systems such as open center systems, constant pressure systems, load sensing systems, hydrostatic transmissions.

CL 2. Discuss the features of the hydraulic control technologies commonly available for servosystems, mobile machinery and industrial applications, particularly in terms of cost, functionality and energy consumption.

CL 3. Formulate, and present the most energy efficient solution for the hydraulic control system of a given fluid power application, given its functional requirements.

CL 4. Apply proper experimental methods for basic troubleshooting of hydraulic control systems.

CL 5. Test and properly report steady state performance of hydraulic control systems, including representing the power losses vs the useful power.

CL 6. Experimentally measure and interpret the basic features of metering control systems including load sensing systems and open center systems

Tentative Schedule

The table below provides the schedule for the minicourse, which will occur from Mon – Thu (whole day) and Fri morning.

Day	Title	Topic	Textbook pages (*)
1. Monday morning (theory)	Single Actuator Control basics	Orifices Interpretation of orifices in fluid power systems: metering, compensator, orifices in pilot lines. Control of single actuator – basic concepts and architectures Flow Supply vs Pressure Supply Primary vs. Secondary regulation Load conditions: resistive and overrunning loads Control of a single actuator: metering configurations Metering control concepts: meter in, meter out Combined metering concept (hydraulic servo)	81-96 261-277 293-329

1. Monday afternoon (lab)		Exp LAB 1 – Introduction to hydraulic – @ Trainer bench – Pump and orifice characterization Exp LAB 2 - Concept of regeneration and regenerative positions Exp LAB 3 – Meter-in, Meter-out, Bleed off (cylinders architecture)	
2. Tuesday morning (theory)	Single Actuator Control advanced	Independent metering Methods for controlling overrunning loads: meter-out and counterbalance valves Open Center systems Basic Open Center – Valve design Advanced Open center systems: Negative and Positive flow control Load Sensing systems for a single actuator Basics of LS control LS systems with fixed displacement pump LS Systems with variable displacement pump Load sensing valve: design and architecture LS pump: controls architecture LS with independent metering valves Electronic LS	333-354 357-377 379-411
2. Tuesday afternoon (lab)		Exp LAB 4 - counterbalance valve (theory and exercise), Sequence circuit, dual pressure circuit Exp LAB 5 – Open center circuit single function	
3. Wednesday morning (theory)	Multiple Actuations	Constant pressure systems Constant pressure system with variable displacement pump Constant pressure system with unloader (CPU) Constant pressure system based on a fixed displacement pump and accumulator Control of multiple actuators: series and parallel actuators Flow dividers and combiners Constant pressure systems for multiple actuators Open center systems for multiple actuators	413-423 427-445 449-454 457-472

		Load Sensing systems for multiple actuators LS systems without pressure compensation (LS) LS pressure compensated systems (LSPC) LSPC with pre-compensated valve technology LSPC with post-compensated valve technology Flow saturation and flow sharing in Load Sensing systems Flow saturation with pre-compensated LSPC Flow saturation with post-compensated LSPC Pre vs Post compensation comparison Independent metering with load sensing	475-509
3. Wednesday afternoon (lab)		Exp LAB 6 – LS circuit – single function Exp LAB 7 – Constant pressure system for multiple user	
4. Thursday morning (theory)	Hydrostatic Transmissions and Actuators	Classifications and theoretical layouts Open circuit hydrostatic transmissions Closed circuit hydrostatic transmissions Applications for propulsions Power split transmissions (*if time allows*) Hydrostatic Actuators and Electro-Hydrostatic Actuators	543-559 560-572 572-581 593-624 631-642
4. Thursday afternoon (lab)		Exp LAB 8 - Multiple user Open Center system Exp LAB 9 - Multiple user Load Sensing system	
5. Friday morning (practice)	Case studies	Case Study: Skid Steer loaders circuit Case Study: Wheel loaders Case Study: Excavator circuits	

(*) textbook pages refer to the book *Hydraulic Fluid Power: Fundamentals, Applications, and Circuit Design* by Andrea Vacca and Germano Franzoni. Purchase of the book is not required. All the class material (slides) will be shared to the class participants (printed copies, pdf).

Cost

Free registration for:

- 1 participant from Maha Fluid Power Research Center Basic Members
- 2 participants from new Maha Fluid Power Research Center Basic Members (joining the center after Sept 2023)
- 3 participants from Maha Fluid Power Research Center Executive Members

$ 1,500 / additional participants from members (*)
$3,500 / participant for non-members (*)
(*) registration priority goes to members benefitting from free registration as detailed above

Registration includes all course material (books not included), lunches, and coffee breaks. No dinner/hotel accommodation provided.