Maha Fluid Power Research Center

Intensive Mini-Course on HYDRAULIC CONTROL SYSTEMS

Tentative dates:
November 14 – 18, 2022

Target audience:
Industry professionals with STEM degree

Course Description

This minicourse covers the fundamental knowledge of fluid power (FP) motion control technology, with particular focus on mobile applications. 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.
The course includes class lectures (mornings) but also some hands-one labs experiences (afternoons). Labs will be performed at the Purdue's Hydraulic Trainers or on the virtual simulator – for online participants.
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.
Tests 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 consists in class lectures. The instructor will present the contents using material previously provided to the participants (pdfs). Additional explanations will be provided using blackboard or similar tools. The participants do not need to purchase additional material, however proper references 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 – 11:00am – problems and solutions
11:00am – 12:00pm – theory
12:00pm – 12:30pm – problem 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. Participants will be divided in groups of max 4 people and will use the Hydraulic Trainer (Fig. 1 below) to perform the experience.
Each lab 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

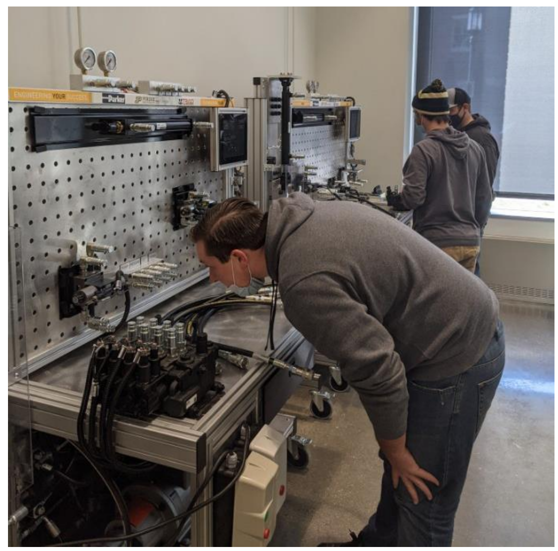

Figure 1 – *Hydraulic Trainers at the Purdue's Parker Hannifin Fluid Power and Motion Control lab*

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 5. There is no test for the Day 5 (study cases).

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 and load sensing systems.

CL 2. Discuss the features of the hydraulic control technologies commonly available for 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 fluid power application, given the functional requirements.

CL 4. Identify and apply proper experimental methods for characterizing steady state performance of pumps

CL 5. 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	Day title	Topic	Textbook pages
1. Monday theory (morning)	refresher	Orifices Interpretation of orifices in fluid power systems: metering, compensator, orifices in pilot lines. Pumps & Motors: basics and efficiency Positive displacement pumps and motors, definitions General principles of operation and energy flow: ideal characteristics Performance of positive displacement units: volumetric and mechanical efficiencies and steady-state characteristics. Control of single actuator – basic concepts and architectures Flow Supply vs Pressure Supply Primary vs. Secondary regulation Load conditions: resistive and overrunning loads	81-96 123-131 261-277
1. Monday lab (afternoon)		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 theory (morning)	Single actuator control	Control of a single actuator: metering configurations Metering control concepts: meter in, meter out principles Pump unloaded lowering Independent metering Open Center systems Basic Open Center – Valve design Advanced Open center systems: Negative and Positive flow control 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	293-329 357-377 413-423
3. Tuesday labs (afternoon)		Exp LAB 4 - counterbalance valve (theory and exercise), Sequence circuit, dual pressure circuit Exp LAB 5 – Open center circuit single function	
4. Wednesday theory (morning)	Single and multiple actuations	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 Control of multiple actuators: series and parallel actuators constant pressure systems for multiple actuators	379-411 427-445 449-454
4. Wednesday labs (afternoon)		Exp LAB 6 – LS circuit – single function Exp LAB 7 – Constant pressure system for multiple user	
5. Thursday theory (morning)	Multiple actuation systems	Open center systems for multiple actuators Load Sensing systems for multiple actuators LS systems without pressure compensation (LS) LS pressure compensated systems (LSPC) LSPC with pre-compensated valve technology	457-472 475-509

		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	
6. Thursday labs (afternoon)		Exp LAB 8 - Multiple user Open Center system Exp LAB 9 - Multiple user Load Sensing system	
5. Friday Practice (morning)	Case studies	Case Study: Aerial platforms and Lift Case Study: Skid Steer series circuit Case Study: Miniex 4-pump circuit Case Study: Medium Excavator circuit	

Attendance

The minicourse will be open to:

- in person partecipants at Purdue University: max 18 participants (min 10 participants)

Cost

Free:

Maha Fluid Power Research Center Basic Members (1 participants)
(**promotion:** 2 participants for new Basic Members)
Maha Fluid Power Research Center Executive Members (3 participants)

$3,500/person for non Maha Fluid Power Research Center Members.

Registration includes all course material, lunch and coffee breaks.
No dinner/hotel accommodation provided.