Lecture 3

• This week – be sure to read your textbook
  • Lab 6: Meter-in and meter-out circuits
  • Lab 7: Bleed-off circuit

• Lab 2 optional resubmit in a week (1 week after reports are returned)
• Feedback from you on labs

• Hydraulic Circuit Analysis
• Power calculation
• Computer Simulation
How labs are going so far?

- What works:
  - Hands-on / interesting / Matlab
  - Helpful TA
  - Small groups / interaction

- What does not work?
  - Flow meter faulty
    - Waiting for new one to arrive;
    - use analog meter and share data for now
  - Matlab
    - Tutorial sessions (not very well attended)
  - Background / reading
  - Reports expectation
    - Rubrics and feedback
How labs are going so far?

• What works?

• What does not work?
  • Power outage; Component failure
Circuit Analysis: Motivation

- Mathematical understanding of how “metering” orifice change affect flow
- Design of the orifices
Analysis of Simple Hydraulic Circuits

Assumptions:
- Incompressible flow
- Steady state conditions

Example 1:
- Ideal constant displacement pump
  - \( Q = 3.5 \text{ gpm all the time} \)
  - Flow meters are ideal

- Find all pressures and flow.
- Justify using Pascal’s law and continuity equation
Computer Modeling of a Needle Valve

\[ Q = C_d A_0 (\text{turns}) \sqrt{\frac{2}{\rho}} (P_1 - P_2) \]

Two options:
- Given delta P and setting (turns), find Q
- Given Q and setting (turns), find delta P

Matlab code:

% orifice1.m
function Q = orifice1(DP, turn)
a0=0.1; a1=0.2; a2=0.3;
K = a0+a1*turn+a2*turn^2;
Q = K*sqrt(abs(DP))*sign(DP);

% orifice2.m
function DP=orifice2(Q,turn)
a0=0.1; a1=0.2; a2=0.3;
K = a0+a1*turn+a2*turn^2;
DP=(Q/K)^2*sign(Q);
**Matlab/SIMULINK Analysis**

- Component described by constitutive relations
  - \( P = f(Q) \) or \( Q = f(P) \)
- Connections with Pascal’s law or continuity
- Relate to non-P/Q variables: \( v = Q/A, \ F = A_1 P_1 - A_2 P_2 \)
Analysis of circuit - valves in series

Example 2:
• Ideal constant displacement pump
  • \( Q = 3.5 \text{ gpm} \) all the time
• Flow meters are ideal
• Find all pressures and flow
• Find \( Q \) versus \( P \) relationship of equivalent needle valve graphically
• If \( N_1 \) and \( N_2 \) are given by:
  \[
  Q = K_1 \sqrt{\Delta P} \quad Q = K_2 \sqrt{\Delta P}
  \]
• Find \( K_{eq} \) in \( Q = K_{eq} \sqrt{\Delta P} \)
Analysis of circuit - valves in parallel

Example 3:

- Ideal constant displacement pump
  - \( Q = 3.5 \text{ gpm} \) all the time
- Flow meters are ideal
- Find all pressures and flow
- Find \( Q \) versus \( P \) relationship of equivalent needle valve graphically

- If \( N_1 \) and \( N_2 \) are given by:
  \[
  Q = K_1 \sqrt{AP} \quad Q = K_2 \sqrt{AP}
  \]
- Find \( K_{eq} \) in
  \[
  Q = K_{eq} \sqrt{AP}
  \]
**Electrical Analog**

- Pressure == Voltage
- Flow == Current
- Orifice == Resistor or conductor?

1. Draw an electrical analog
2. Analyze the electrical circuit

What are the similarities and differences?
- Equivalent orifice/resistance
- Nonlinearity
Can you analyze the PCFC now?

- Mathematical understanding of how “metering” orifice affect flow
- Design of the orifices
**Power flow**

- **Mechanical power:**
  - Power = Force [N] * velocity [m/s] ;
  - Power = Torque [Nm] * angular velocity [rad/s]

- **Hydraulic power (assume incompressible):**
  - Power = Pressure [Pa=N/m\(^2\)] * Flow [m\(^3\)/s] = P * Q

Why?

What is the force acting on the piston?
What is the velocity?
Power consumed in a component

- Power in =
- Power out =
- Power consumed (or generated) =

Application to a needle valve: ?
**Meter-In Circuit Analysis (Simplified)**

Find

- Cylinder cap-side pressure, P
- Flow out $Q_{\text{out}}$
- Circuit efficiency

![Diagram of Meter-In Circuit Analysis](image)
**Meter-out circuit**

- Better control of over-running load
- Pressure intensification

![Diagram](image-url)
Meter-in and Meter-out Circuits

• How does flow control translate to actuator velocity control?
• At least 4 locations to put control valve
• Opposing load versus over-running load
• Pressure intensification
• Energy loss – where is the energy going?
  • Ideas for more efficient circuits?
Bleed Off Circuit
Limitation in Meter-in/Out Lab

- Difficult to create a resistive load (safely) on the cylinder
  - Use a throttling valve downstream to mimic a load

- Cannot create over-running load