ME 4232:
FLUID POWER CONTROLS LAB

Class #8
Servo-Hydraulic Systems
Notes

• Issues w/ Integrated Lab?

• System Dynamics Review Assignment
  – Due Mon/Tues lab after break (3/24-25)
  – Counts as a lab assignment

• Upcoming Labs:
  – Lab 15: Intro to Electro-Hydraulic Control Setups & Open Loop System Identification
Agenda

• Servo Valves
  – Function
  – Characteristics
  – Experimental System
  – Valve Sizing
  – Open-Loop System Identification
Previously Discussed:
Directional Control Valves

Diagram:
- Pressure to “B” and “A” to tank
- Pressure to “A” and “B” to tank
Single Stage Proportional Valves

- Solenoids Create Spool Displacement
- LVDT Spool Position Feedback
- Spring (sometimes) for Safety
Single Stage Proportional Valves

- **Advantages:**
  - Simple design
  - Reliable
  - Cost effective

- **Disadvantages:**
  - Poor dynamic performance (bandwidth)
  - At high flow rates and bandwidths, large stroking force is needed
  - Large (and expensive) solenoids / torque motors needed.
  - Low end market …..
Multi-stage valves

- Use hydraulic force to drive the spool ….
Electrohydraulic servo-valve

- Multi-stage valve
- Typically uses a flapper-nozzle pilot stage
- Built-in feedback via feedback wire
- Very high dynamic performance
- Bandwidth = 100-200+Hz

For a fun place to learn how a servo-valve works:
R. Dolid “Electrohydraulic Valve Coloring Book”
Servovalves

Servo-Valve Diagrams from:
Dolid, R., 2010, “The Electrohydraulic Servovalve Coloring Book,”
1. Rotation of the torque motor restricts one jet and allow free flow through the other. What effect does this have on spool force balance?

2. How does the second stage provide closed-loop feedback to the first stage?
First Stage – Torque-motor-armature

Transforms electrical current into torque, which changes relative nozzle pressures

A. Permanent Magnet (2) - yellow
B. Wire Coil - pink
C. Armature Assembly – light blue
D. Upper Pole Piece – light green
E. Lower Pole Piece – dark green
First Stage - Armature rotation
First Stage – Nozzle and Flapper
Second Stage

J. Feedback wire – orange
K. Nozzles – red
L. Spool – dark blue
M. Filter – brown
N. Fixed Orifice – light green
O. Variable orifice – dark green
Null Position – Oil Flow path

1. Supply pressure - red
2. Filter pressure – light blue
3. Spool press. – orange
4. Return press – light green
Activated Position – Oil Flow Path

1. Supply - red
2. Filter – light blue
3. Spool hi-side – pink
4. Spool lo-side – yellow
5. C1 – orchid/magenta
6. C2 – dark blue
7. Return press – light green
Servo Valve Parts

1. Spool
2. Nozzle
3. Fixed Orifice
4. Tubular Filter
5. Disc Filter
Torque Motor Parts

1. Torque motor armature assembly with signal connector
2. Permanent magnet
3. Electromagnet coil
4. Armature/flexure tube/flapper/feedback wire assembly

1. Upper and lower pole pieces
2. Permanent magnet
3. Electromagnet coil
4. Feedback wire
Three Stage Valve

First Stage
- Coil
- Magnets
- Upper Pole Piece
- Flexure Tube
- Lower Pole Piece
- Flapper
- Feedback Wire
- Fixed Orifice

Second Stage
- Nozzle
- Second (Pilot) Stage Spool
- Filter

Third Stage
- Pilot Return
- Core
- Return
- LVDT Transformer
- Pressure
- Pilot Pressure
- Third (Main) Stage Spool
MTS Systems Corp – 4000 gpm Valve

MTS Systems Corporation
15,000 Liter per Minute Servovalve
Nozzle & Flapper vs. Jet Tube
Servo Valve Benefits / Characteristics

• Feedback from 2\textsuperscript{nd} Stage to 1\textsuperscript{st} Stage
• Low Mass Torque Motor
• Large ΔP in 1\textsuperscript{st} Stage
• Frictionless / Isolated 1\textsuperscript{st} Stage
• Mechanically / Hydraulically Symmetric
• 300-1000 Hz Natural Frequency
• Good Linearity
Negatives

- Contamination Susceptible
  - < 3 micron filtration

- High Cost
  - Torque motor
  - Critically Lapped
## Servovalve vs. Proportional Valve

<table>
<thead>
<tr>
<th></th>
<th>Servovalves</th>
<th>Proportional Valves</th>
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<tbody>
<tr>
<td><strong>APPLICATION</strong></td>
<td>- Closed Loop</td>
<td>- Open Loop</td>
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<tr>
<td><strong>COST</strong></td>
<td>- Higher, can be expensive</td>
<td>- Lower</td>
</tr>
<tr>
<td><strong>SPOOL</strong></td>
<td>- Spool and Sleeve</td>
<td>- Spool and Body</td>
</tr>
<tr>
<td><strong>NULL CONDITION</strong></td>
<td>- Axis cut (zero lap)</td>
<td>- Large Overlap, 20% for ex.</td>
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<tr>
<td><strong>SPOOL STROKE</strong></td>
<td>- Shorter</td>
<td>- Longer</td>
</tr>
<tr>
<td><strong>Dynamic Performance</strong></td>
<td>- Excellent</td>
<td>- Lower</td>
</tr>
<tr>
<td><strong>Static Performance</strong></td>
<td>- Excellent</td>
<td>- Lower, can be poor.</td>
</tr>
<tr>
<td><strong>Size and Weight</strong></td>
<td>- Mostly smaller</td>
<td>- Mostly bigger</td>
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New Experimental Systems