Design and Modeling of Fluid Power Systems
ME 597/ABE 591    Lecture 10

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Contents

- Proportional valves - servovalves
- Electromechanical actuators - overview
- Pilot operated proportional valves
- Internal feedback systems
- Pressure – flow metering characteristics

Experimental determination of:
- Flow gain, pressure gain
- Dynamic characteristics
- Linearization of pressure/flow characteristics
Proportional Valves

Electromechanical actuator

Proportional solenoid

Single or multiple stage

controlled hydraulic power

hydraulic power supply

Signal

$x_e = i_e$

$x = F$

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Circuit simplification

Velocity control

with one way restrictor valve

with proportional valve
Electromechanical actuators

as input device of proportional & servovalves

<table>
<thead>
<tr>
<th></th>
<th>Proportional Solenoid</th>
<th>Moving Coil</th>
<th>Torquemotor</th>
<th>Lineararmotor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coil</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Armature</strong></td>
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<td><strong>Permanent magnet</strong></td>
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<td><strong>Torsion spring pivot</strong></td>
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| Power [W]   | 5 ... 40 | 0,2 ... 5 | 0,02 ... 4 | 10 ... 40 |
| Work [Nmm] | 20 ... 1000 | 8 ... 80 | 2 ... 40 | 400 ... 2000 |
| Linearity [%]| 0,5 ... 6 | 1 ... 7 | 1 ... 2 | 0,5 ... 6 |
| Bandwidth [Hz]| 10 ... 150 | 100 ... 200 | 100 ... 300 | 10 ... 200 |
Proportional valves

Direct operated

Direct operated with internal closed position control loop
Pilot operated proportional valves

Using pressure reducing valve

Using pressure relief valve

Internal position control of main spool by force feedback

Internal position control of main spool by electric position feedback)
Servovalve

Single and Two-stage electrohydraulic servovalves

1st stage (pilot stage) + Flapper-nozzle + Main spool

or Jet Flapper system
Flapper nozzle system

Double jet flapper valve

\[ \Delta p \sim y \]

\[ \Delta p = p_1 - p_2 \]

Measured curve

\[ \frac{\Delta p}{p_0}, \frac{p_1}{p_0}, \frac{p_2}{p_0} \]
Jet Flapper system

Good linear behavior
Servovalve with mechanical feedback
Servovalve with mechanical force feedback
Servovalve with hydraulic force feedback
Servovalve with electrical position feedback
Single stage servo valve
Pressure – flow curve

\[ \frac{Q}{Q_{\text{max}}} \]

\[ \frac{y}{y_{\text{max}}} \]

\[ \frac{p_L}{p_S} \]

Power loss
Pressure – flow curve measurement

Power Supply

Test valve
Measurement of flow gain
Measurement of pressure gain

Power Supply

Tested Valve
Measurement of frequency response

Amplitude ratio [dB]

Phase angle [°]

Frequenz [Hz]

±100%

±25%

±5%

±100%
Linearization of pressure-flow curve

Using Taylor Series expansion

\[ Q = B \cdot y \sqrt{\frac{1}{2}} (p_0 - p_L \cdot \text{sign}(y)) \quad \rightarrow \quad Q = C_Q \cdot y - C_{Q,p} \cdot p_L \]
SV - Linear model

\[ \ddot{y} + 2d \cdot \omega_0 \cdot \dot{y} + \omega_0^2 \cdot y = V_{SV} \cdot \omega_0^2 \cdot i \]

\[ Q_L = C_Q \cdot y - C_{Q,p} \cdot p_L \]

Two stage servovalve zero lapped

\[ Q_L = C_Q \cdot y - C_{Q,p} \cdot p_L \]
Valve controlled actuator