Load sensing technologies
Load sensing technologies

What is load sensing?

“Sensing the load pressure downstream of an orifice and...

...adjusting the pump flow rate to maintain a constant pressure drop across the orifice...

...meaning a constant flow is achieved regardless of a change in load pressure”

- Non-compensated and compensated valves
  - Load dependent and load independent with multiple functions

- Types of compensation
  - Pre compensated (Load sensing) & Post compensated (Flow-sharing / LUDV)

“Lastunabhängige Durchflussverteilung”
Load sensing technologies

What is load sensing?

Open Center LS

Closed Center LS
Load sensing technologies

What is load sensing?

Open Center LS

Closed Center LS
Load sensing technologies

Flow Equation

\[ Q_V = \alpha \times A \times \sqrt{\frac{2}{\rho} \times \Delta p} \]

\[ \alpha \times \sqrt{\frac{2}{\rho}} = K \]

\[ Q_V = f (A, \Delta p) \]

\[ \Delta p = \text{const.} \]

\[ Q_V = f (A) \]

**Load-dependent System**
(Open Center Control)

**Load-independent System**
(Load Sensing Control)

- \( Q_V \) = Flow
- \( A \) = Opening area of orifice
- \( \Delta p \) = Differential pressure
- \( \alpha \) = Flow coefficient
- \( \rho \) = Oil Density
Load sensing technologies

Under-saturation condition

<table>
<thead>
<tr>
<th>q_{pump} [l/min]</th>
<th>A_{valve} [mm²]</th>
<th>(\Delta p) [bar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>18.5</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>36.9</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>55.3</td>
<td>8.9</td>
</tr>
<tr>
<td>Max 100 l/min</td>
<td>73.8</td>
<td>5</td>
</tr>
</tbody>
</table>

\(\Delta p\) represents the pressure drop across the valve. A_{valve} is the valve area, and q_{pump} is the pump flow rate.
Load sensing technologies
Pre- and post-compensation – basic circuits

Pre-compensated

Load sensing pump

Pressure compensator (normally open)

Metering element (main spool)

Actuator (cylinder or motor)

Bias spring

Load signal check

Post-compensated

Load sensing pump

Pressure compensator (normally closed)

Metering element (main spool)

Actuator (cylinder or motor)

No bias spring

Load signal check
Load sensing technologies
Pre-compensation - basic circuit

- Start of movement load-/flow-independent
- Fine control range load-independent but flow-dependent
- Independent movement during parallel operation
Load sensing technologies
Pre-compensation - saturated condition

Load 50 bar
Load 250 bar

Required flow 60 l/min
Required flow 30 l/min

50 bar
250 bar

Max flow = 100 l/min
FR = 20 bar

Δp 213 bar
Δp 7 bar
Δp 13 bar

57 bar
257 bar

Bias spring 7 bar
Bias spring 7 bar

7 bar
7 bar
Load sensing technologies
Pre-compensation - under-saturated condition

Pre-compensation - under-saturated condition

Load 50 bar
Required flow 80 l/min
Actual flow 80 l/min
Load 250 bar
Required flow 50 l/min
Actual flow 20 l/min

Load 50 bar
Load 250 bar

50 bar
250 bar

Bias spring 7 bar
Bias spring 7 bar

FR = 20 bar
Max flow = 100 l/min

Δp 7 bar
Δp 194,1 bar
Δp 1,1 bar
Δp “0” bar

Δp = \frac{Q^2 \cdot \rho}{A^2 \cdot \alpha^2 \cdot \Delta p} = 1,1 bar

Δp = \frac{Q_V}{\alpha \cdot \sqrt{\Delta p}} = 31,2 mm^2

A = \frac{Q_V}{\alpha \cdot \sqrt{\Delta p}} = 31,2 mm^2

50 l/min
7 bar
20 l/min
31,2 mm^2

7 bar
1,1 bar
31,2 mm^2

57 bar
251,1 bar
250 bar
251,1 bar
251,1 bar
Load sensing – pre-compensated circuit
Consumer flows with reduced pump flow

\[ p_3 > p_2 > p_1 \]

1. Total flow
2. Pump flow
3. \( q_\text{Pu} \) [%]
Load sensing – pre-compensated circuit

**LS pressure limitation**

- Function analogue to pressure cut-off
- Limitation of the LS-signal, therefore nearly free of losses
- Local as well as global pressure limitation is possible
Load sensing – pre-compensated circuit

LS unloading

- LS unloading is realized through the main spool
Load sensing – pre-compensated circuit
Example: M4-12 High pressure load sensing control block
Flow sharing (LUDV) – post compensated circuit

Basic circuit

- Start of movement load-/flow-independent
- Fine control range load/flow-independent
- Independent movement during parallel operation
Flow sharing (LUDV) – post compensated circuit

Saturated condition

Load 50 bar

Required flow 60 l/min

Load 250 bar

Required flow 30 l/min

Δp 200 bar

Δp 20 bar

Δp 20 bar

Δp “0” bar

50 bar

250 bar

250 bar

250 bar

270 bar

270 bar

FR = 20 bar

Max flow = 100 l/min

50 bar

250 bar

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Flow sharing (LUDV) – post compensated circuit

Undersaturated condition

Load 50 bar

Load 250 bar

Required flow 80 l/min
Actual flow 61.5 l/min

Load 250 bar

Required flow 50 l/min
Actual flow 38.5 l/min

Δp 200 bar
Δp 11.8 bar

Δp "0" bar
Δp 11.8 bar

50 bar
250 bar
250 bar
261.8 bar

FR = 20 bar
Max flow = 100 l/min

FR = 20 bar
Max flow = 100 l/min

11.8 bar
130 l/min
Flow sharing (LUDV) – post compensated circuit

**Flow sharing**

**Consumer 1**
- $Q_{\text{required}} = 80,0\ l/min$
- $Q_{\text{actual}} = 61,5\ l/min$
- Ratio = $1 : 0.77$

**Consumer 2**
- $Q_{\text{required}} = 50,0\ l/min$
- $Q_{\text{actual}} = 38,5\ l/min$
- Ratio = $1 : 0.77$

**Pump**
- $Q_{\text{required}} = 130,0\ l/min$
- $Q_{\max} = 100,0\ l/min$
- Ratio = $1 : 0.77$
Flow sharing (LUDV) – post compensated circuit

Consumer flows with reduced pump flow

\[ p_3 > p_2 > p_1 \]
Flow sharing (LUDV) – post compensated circuit

End stop condition

$P_{\text{pump}} = P_{\text{LS}}$

$\Rightarrow \Delta p = 0$

No flow can pass through compensator
Flow sharing (LUDV) – post compensated circuit
LS pressure limitation

\[ \Delta p = 20 \text{ bar} \]

\[ FR = 20 \text{ bar} \]

\[ DR = 300 \text{ bar} \]

\[ LSRV = 280 \text{ bar} \]
Flow sharing (LUDV) – post compensated circuit

Port pressure limitation

- Local port pressure limitation only possible via full flow shock valves
- High loss and heating
- Only global LS pressure limitation is possible
Flow sharing (LUDV) – post compensated circuit
LS unloading
Post compensated circuit (LUDV)

Example: M7-22 High pressure flow sharing control block
Combination circuit
LS and LUDV – checklist

1) Check valve from pre-compensated LS-signal to common LS-signal
2) LS copy valve (if necessary)
3) No valves in the LS line between pump and LUDV valve
4) Main relief valve (or PC)
5) LS relief valve setting = pump standby pressure **below** the MRV (or PC)
6) LS unloading valve
Combination circuit
LS and LUDV – system features

- LS circuit will have priority over the LUDV circuit in under-saturated condition
- LUDV circuit will share the remaining flow when the required LS functions are saturated
## Load sensing technologies

### Summary of features

<table>
<thead>
<tr>
<th>LS (pre-compensation)</th>
<th>LUDV (post-compensation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good fine-control</td>
<td>Good fine-control</td>
</tr>
<tr>
<td>Start of movement load-independent</td>
<td>Start of movement load-independent</td>
</tr>
<tr>
<td>Load-independent parallel operation of several actuators under <strong>saturated</strong> condition</td>
<td>Load-independent parallel operation of several actuators also under <strong>under-saturated</strong> condition</td>
</tr>
<tr>
<td>Possibility for local LS pressure limitation</td>
<td>No possibility for local LS pressure limitation</td>
</tr>
<tr>
<td>Load-dependent under <strong>under-saturated</strong> condition, i.e. system reacts like throttle control</td>
<td>Sensitive against oscillations, therefore intensive prototype commissioning may be necessary</td>
</tr>
</tbody>
</table>
Thanks for your attention