Improved drive dynamics and enhanced accuracy by PT_1- instead of P-controller

The statement that hydraulic drives are difficult to control is certainly exaggerated. But there are some things to keep in mind. An important point is to achieve the maximum possible closed loop gain [V_0] of the controlled positioning drive.

All POS controllers (Example: UHC-126)

$V_0 \leq 2 \cdot d \cdot \omega_0$

This typical calculation (for a 3rd order system) describes the stability limit. In practice, a significantly lower gain must be set. Considering a hydraulic drive with a typical degree of damping [d] = 0.1, the result is $V_0 \leq 0.07 * \omega_0$, in case that overshoot-free positioning is desired.

Example drive:

Natural frequency = 16.67 Hz ($\omega 0 = 100\ s^{-1}$), damping = 0.1

Closed loop gain (stability limit) = 20 s^{-1}

Closed loop gain (typical) = 10 s^{-1}

Closed loop gain (overshoot-free) ≤ 7 s^{-1}

Can the control behaviour be improved without great effort?

The critical factor of the hydraulic system is the low damping, which leads to an increased tendency to oscillate. If the drive is damped, the tendency to oscillate is reduced. The simplest and most straightforward method is to use a PT_1 controller. The PT_1 controller delays the control of the hydraulics, resulting in a significantly improved damping. This allows a higher loop gain to be set.

How should such a controller be adjusted?

Our investigations have shown that the optimum time constant for the controller is 63 % of the time constant of the hydraulic cylinder and that the closed loop gain can be increased by 50 %.

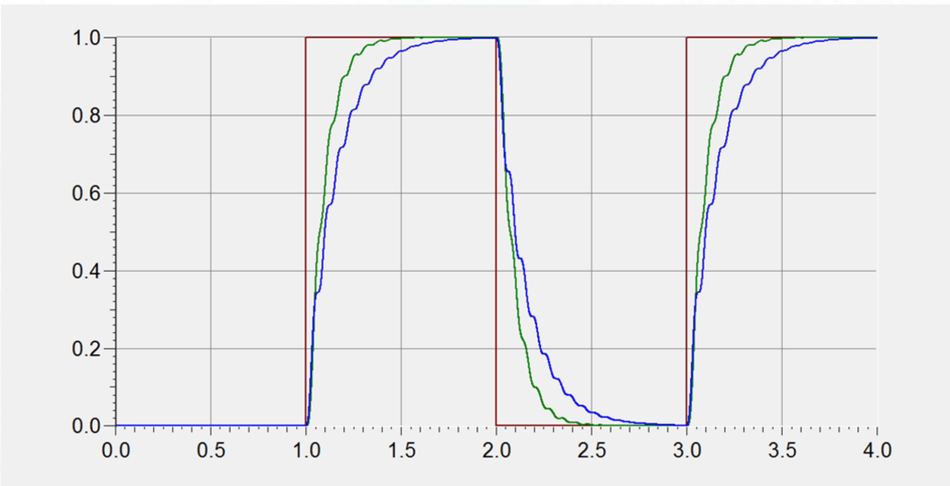
The typical setting for this example system is therefore $V_0 = 15\ s^{-1}$ and t = 0.015 s.

What in the influence of the proportional valve?

If we artificially delay the control behaviour of the system with a PT_1-controller, can't we simply use a slower valve (valve with a lower natural frequency)? In principle, yes. A slow valve also dampens the drive. Unfortunately, the valve cannot be adapted to the drive. However, if the natural frequency is in the range of 50... 75% of the cylinder's natural frequency, the PT_1-controller can be omitted. Another technical disadvantage of classic proportional or control valves is their dynamic non-linearity. The valves have a significantly higher natural frequency for small amplitudes (small volume flows) than for large amplitudes. The valves become more dynamic whenever more damping is required. In this respect, the PT_1-controller is superior because it always produces the same dynamics regardless of the amplitude.

Summary of the results:

- The advantages are higher dynamics and better positioning behaviour (see picture below).
- A highly dynamic valve in combination with a PT_1 - controller yields the best results.
- Relatively slow valves, which produce a PT_1 - like behaviour, can lead to a very satisfactory control response, even without a PT_1-controller.



RED = setpoint, BLUE = actual value with a P-controller, GREEN = actual value using a PT_1-controller. Both controllers have been set such that no overshoot occurs.