Supplementary Materials: Physical Modeling of a Water Hydraulic Proportional Cartridge Valve for a Digital Twin in a Hydraulic Press Machine

Oscar Bautista Gonzalez and Daniel Rönnow

1. Supplementary material

This section presents the Matlab/Simulink (see Figure S1) used to obtain the model output while assuming water was compressible to study the relative errors in the elements of $\hat{\theta}_3$ in contrast with the assumption in Equation (4) of water being incompressible; see Table 5 row (k). The model was split into three parts: the pilot valves of groups (I) and (II) and the main valve; see Figures 1 and 2. The block related to the pilot valves (I) sends Q_{in} to the main valve block, which sends back P_c. The block related to pilot valves (II) sends Q_{out} to the main valve block, which sends back P_c. One of the main valve block outputs is the position of the spindle x, which is the feedback to the same block to calculate the volume of (X); see Figures 1 and 2.

The blocks related to the pilot valves contain Equation (1) to Equation (3). The block labeled as the main valve includes Equation (4) and Equation (7). In this case,

$$\dot{P}_c = \frac{\beta}{V_o + A_B x}(Q_{in}(\overline{v}_{in}, P_c, t) - Q_{out}(\overline{v}_{out}, P_c, t)) - A_B \dot{x}) \tag{1}$$

was used to replace Equation (4), where β is the fluid bulk modulus of water and V_o is the initial volume of water in (X); see Figures 1 and 2. The parameters of each equation were selected according to Table 3. The generated input signals $\overline{v}_{in}$ and $\overline{v}_{out}$ were similar to the ones in Figure 4b.

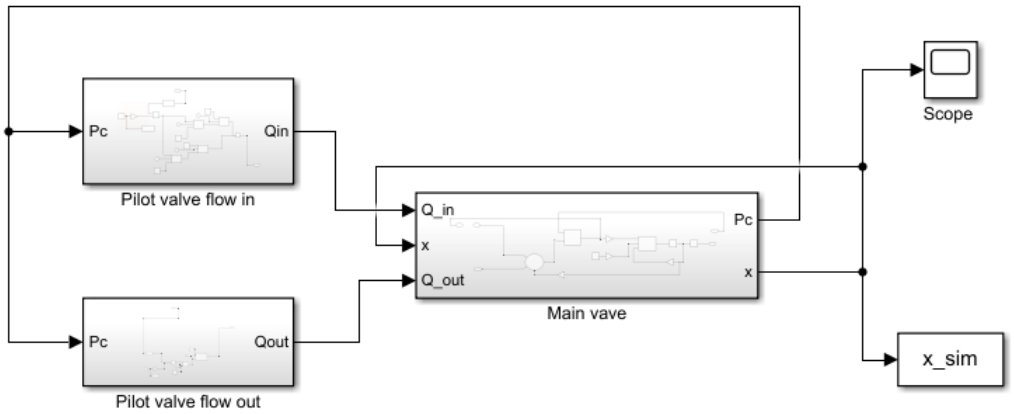

Figure S1. Simulation model of the water hydraulic proportional cartridge valve considering the effects of compressibility. Three blocks were used: pilot valve flow-in represents the pilot valves in (I), pilot valve flow-out represents the pilot valves in (II), and the main valve; see Figures 1 and 2.