Application

Hydraulic Axial Piston Pump

Introduction
The enhancement of the performance of hydraulic pumps is still a major task for hydraulic component manufacturers. They focus their activities to improve the characteristics regarding delivery rate, fluctuation, efficiency, suction behavior and noise generation. Hydraulic pumps are very complex systems with fast changing working conditions. Nowadays only the experimental analysis are ineffective and not all, e.g. for optimization, relevant quantities can be measured. The design and dimensioning as well as the optimization can be supported by appropriate simulation tools, like SimulationX.

Modeling of an Axial Piston Pump
Figure 1 shows a sectional view of an axial piston pump. A piston stroke is generated by the rotation of the cylinder and the at the swash plate mounted piston. The alternating connection of the piston chamber between suction and pressure side, creates a volume flow, which depends on the swash plate angle. The design of the respective transition regions of the control disc influences almost all characteristics of the pump:
• cavitation
• efficiency
• noise generation
• fluctuation
• suction flow limitation
• control torque, ...

Depending on the problems, which have to be analyzed, different levels of modelling depth can be realized. Beginning with the model of a single piston the application will be extended up to a complete model of a variable adjustable axial piston pump including swash plate stroke cylinder and control valve.

System Structure and Model
Figure 2 displays the definition of required variables at the pump components.

Figure 1: Section View Swash Plate Pump
(Source: Paetzold, Hemming; Hydraulik und Pneumatik, Verlag Christiani, Konstanz, 1996)

Figure 2: Definition of variables at barrel, piston, swash plate and control disc
Single Piston Model

Initial point for modeling the complete pump is a model of a single piston. The internal structure (see Figure 3) consists of elements from the Mechanics, Hydraulics and Signal Blocks libraries. Finally the complete structure is grouped together to a compound (SimulationX substructure). This compound allows an easy handling, e.g. duplicate for more than one piston machines, and a clear structuring for bigger models.

The one piston model includes the functional description of:

- the translational motion of the piston in the piston chamber with changing volumes and
- the barrel rotation angle dependent inlet and outlet cross section areas.

Control Disc

The dependency between flow cross section area of inlet or outlet port and the rotation angle are defined by curve elements. These curve characteristics could be measured data or data from other CAD-programs as well as fictive characteristics defined by the user themselves to achieve the required behavior.

For optimization and pre-design is the behavior analysis of the one piston model absolute adequate. The most of ongoing processes in the one piston model will be repeated at different rotation angles in the case of multi piston pumps.

Evaluation criteria for the design of pumps are for example the pressure and the compression volume flow in the piston chamber. The measurement of these two quantities in reality is difficult but they are important for a prediction of the expected pump properties.

Figure 4 shows the simulated results of chamber pressure build-up for two different shaped control discs. All result quantities are displayed over the barrel rotation angle. The raising chamber pressure and flow in the case of control disc A shows a discontinuity. After an optimization of cross section areas the discontinuity could be minimized.
Axial Piston Pump (9 Pistons)

For system simulation, the one piston model will be extended to a model of a 9 piston axial piston pump with variable adjustable swash plate, see Figure 5. Therefore the kinematics of the swash plate, a stroking cylinder and a control valve are implemented into the model. The pump is driven by a motor. Pump and motor are connected via a shaft modeled as a spring damper. Furthermore the model is extended by elements of the Multi-Body-System (MBS) library. So it is possible to consider moved inertias either in the one dimensional single piston model or in the MBS elements. Finally the MBS model part allows a 3D representation and animation of the pump which can be observed during and after the simulation.

Figure 5: SimulationX model of a 9-piston axial piston pump: 3D-view and model structure
Results

The model of the 9 piston pump can be used for example in a system simulation with elements and components of the prospected system configuration. In combination with pipe and hose line elements of the SimulationX Hydraulics library studies about pressure and flow fluctuation can be done. A point of interest for controller design is the dynamic behavior of swash plate and control valve.

The model shown in Figure 5 is used to simulate a pump speed run up from 0 to 1500rpm. The pump is acting against a constant throttle valve which represents the load. The control valve pressure is set to 50bar. Figure 6 displays input signal of pump speed and the results of swash plate angle, outlet pressure and flow. After starting with the maximum swash plate angle the control valve opens near 50bar system pressure and the swash plate begins to reverse. Caused by limited cross section areas inside the control valve and the inertias of control valve, stroking piston and swash plate an overshooting in system pressure takes place. Finally the pressure is stabilizing at the adjusted control valve set pressure of 50bar.

![Graphs showing pump speed, swash plate angle, outlet pressure, and flow](image)

Figure 6: Simulation results of pump speed and swash plate angle, outlet pressure and volume flow for a pump speed run up (control valve set pressure 50bar)

Further model results of pump power requirement and needed torques, e.g. swash plate control torque, assist the design engineer in dimensioning adequate drive structures.

Conclusion

The presented application shows that the graphic-interactive and object-orientated concept of SimulationX enables the user to create models of complex hydraulic systems in a fast and efficient way. SimulationX supports the design, analyzing and optimizing of dynamic systems with complex coupled problems in the fields of hydraulics, mechanics (1D and 3D) and control structures.