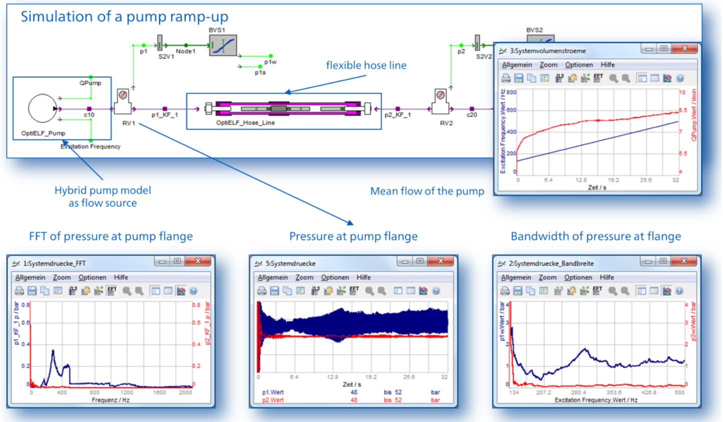
acteristic flow ripple and impedance of the pump.

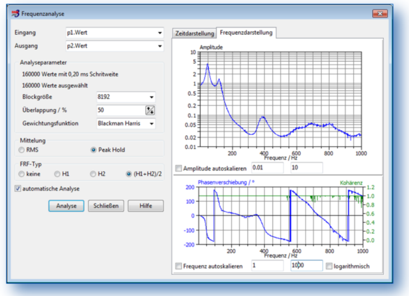
How RohrLEx analyses and solves the problem

Now that RohrLEx has all the component models required to assemble his fluid power system, he can start the time domain simulation with DSHplus. A major advantage of the time domain simulation compared with the frequency domain simulation is



the fact that nonlinearities and certain types of boundary conditions can be taken into account. Due to the modularity of the simulation model, RohrLEx can first analyse the validated components, independently from the original system to which they are attached, and then combine them to a new and optimised system.

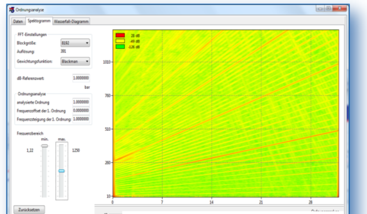
When analysing the results, RohrLEx makes use of the virtual engineering lab tools provided by DSHplus. For frequency domain analyses, DSHplus offers a fast Fourier transform, calculation of the frequency response and an order analysis. One of the main advantages of analysing the calculated results



in the frequency domain is the fact that small amplitudes of a certain frequency can be identified very easily, even if they are superimposed by amplitudes with substantially higher amplitudes at other frequencies.

With the frequency analysis tool, RohrLEx can calculate the frequency response of two signals. To illustrate the transfer function, a Bode diagram is plotted. In addition to amplitude and phase angle, also the coherence function of the two signals is calculated.

RohrLEx uses the order analysis to generate a spectrogram. The amplitude of every point at a certain frequency and point of time (third dimension) is depicted through a colour scale in the graph. If the excitation increases linearly with time, single frequency shares can be isolated from the signal.


Campell-Diagram of a pump ramp-up

The unique combination of DSHplus and specifically tailored test benches enables it RohrLEx, FLUIDON's engineering service provider, to rapidly analyse the acoustic behaviour of arbitrary pipe (and hose) networks and solve the pressure oscillation problems of the customer.

About FLUIDON and RohrLEx

Fluid power is our passion, in theory and practice. We place our know-how and our competence to your disposal to realise your ideas and to solve problems.

On theoretical side, our simulation tool DSHplus assists us in, for example

- checking circuit conceptions and ensuring system functionality
- calculating, analysing, and optimising system dynamics
- investigating oscillations in piping systems

In practice, our project-specific equiped test rigs enable us to support simulations by measurements. Typical tasks are

- parameter identification e. g. of valves and pumps
- determination of transmission behaviour of hoses and pipes
- measurements for validation of simulation models

The combination of both, marks us as prime address for all those, who are engaged in simulation based design and development of fluid power systems.

In this context, RohrLEx represents our activities in the field of simulation, analysis, and optimization of pressure pulsation phenomenons in hydraulic pipe networks.

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Pressure Pulsation Analysis with RohrLEx, FLUIDON's Pipe Expert

Simulate
Analyse
Realise

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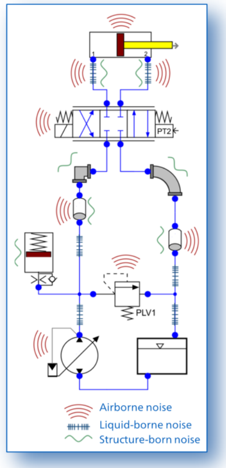
Simulate Analyse Realise

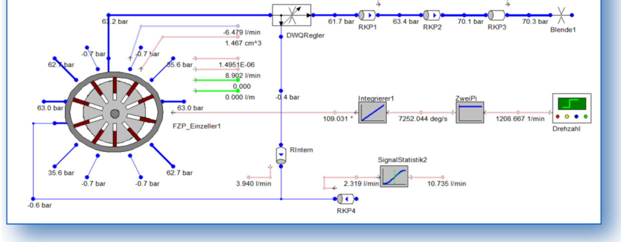
Pressure Oscillation Analysis with RohrLEx



Due to his vast experience, FLUIDON´s pipe expert RohrLEx is aware that pressure and flow ripple in fluid power systems are frequent causes of problems and complaints. The pulsations are of particular concern if the ripple frequencies match the natural frequencies of the pipe network. The ripple causes fluid-borne noise that propagates through the pipe network and excites the surrounding parts to vibrate. This induces undesirable noise emissions, unfavourable dynamic structural loads and naturally, a general reduction of the reliability of the hydraulic system.

RohrLEx also identified positive displacement pumps as the main source of fluid-borne noise. Due to the discontinuous operating principle of these pumps, the flow discharge delivered to the pipe network consists of a mean, stationary flow with superimposed periodic fluctuations. If the pump is operated with varying rotational speed as is the case with frequency controlled pump drives or vehicle and mobile hydraulic systems, the periodic fluctuations excite the pipe network with a broad spectrum of frequencies, rapidly increasing the risk of resonance problems to occur.

Detailed simulation model of a vane pump with flow controller

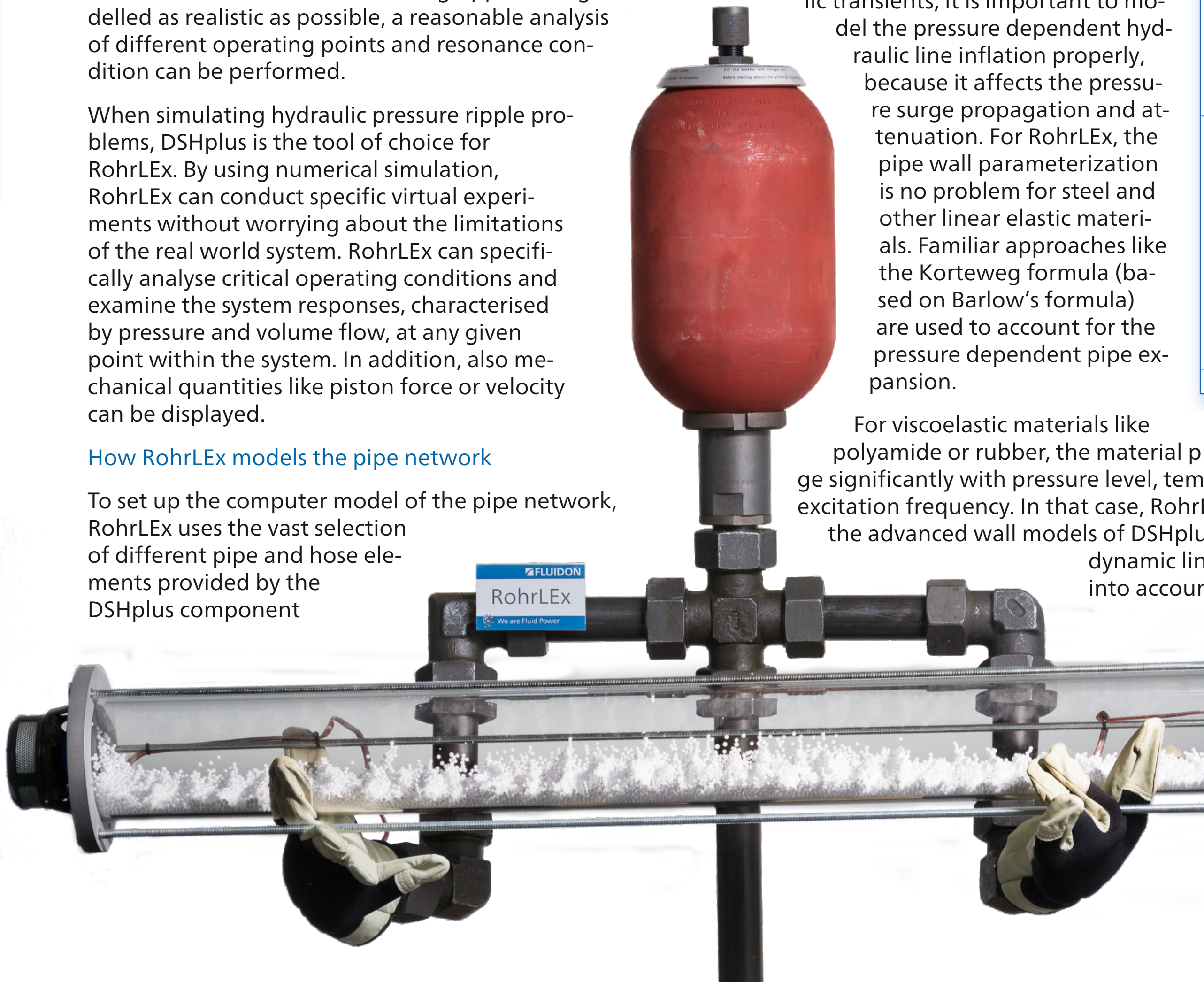


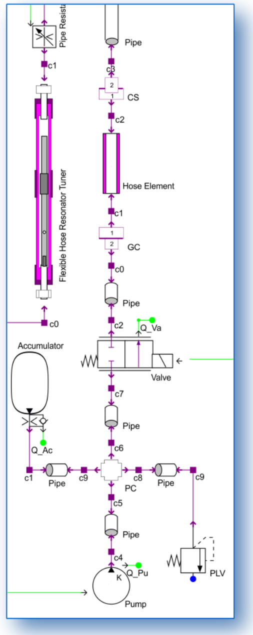
To obtain reasonable results when performing a pressure ripple analysis, RohrLEx recommends that all components connected to the pipe network should be taken into account. With the exciting ripples being modelled as realistic as possible, a reasonable analysis of different operating points and resonance condition can be performed.

When simulating hydraulic pressure ripple problems, DSHplus is the tool of choice for RohrLEx. By using numerical simulation, RohrLEx can conduct specific virtual experiments without worrying about the limitations of the real world system. RohrLEx can specifically analyse critical operating conditions and examine the system responses, characterised by pressure and volume flow, at any given point within the system. In addition, also mechanical quantities like piston force or velocity can be displayed.

How RohrLEx models the pipe network

To set up the computer model of the pipe network, RohrLEx uses the vast selection of different pipe and hose elements provided by the DSHplus component library. Even the most complicated pipe networks can be modelled with the supplied parts for valves, resistances, branches, hydraulic accumulators and sudden diameter changes. When simulating hydraulic transients, it is important to model the pressure dependent hydraulic line inflation properly, because it affects the pressure surge propagation and attenuation. For RohrLEx, the pipe wall parameterization is no problem for steel and other linear elastic materials. Familiar approaches like the Korteweg formula (based on Barlow's formula) are used to account for the pressure dependent pipe expansion.





For viscoelastic materials like polyamide or rubber, the material properties change significantly with pressure level, temperature and excitation frequency. In that case, RohrLEx has to use the advanced wall models of DSHplus to take the dynamic line expansion into account.

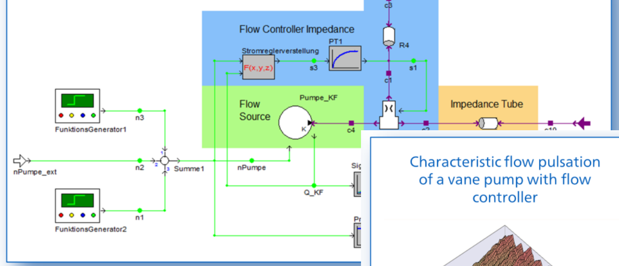
If required, RohrLEx can use the specialised pipe test benches provided by FLUIDON to identify missing material parameters by experiment.

How RohrLEx models the hydraulic excitation

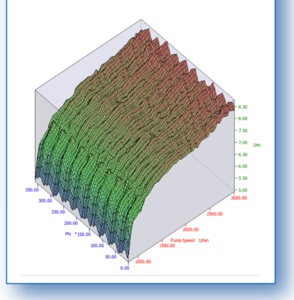
To complete the pressure ripple analysis with DSHplus, RohrLEx requires a pump model which reproduces the characteristic pressure and speed dependent flow ripple as well as the pump impedance.

RohrLEx uses a hybrid pump model developed by FLUIDON which is based on the real pumps flow characteristics that were measured by using special techniques such as the secondary source method or impedance matching.

Hybrid simulation model of a pump



Characteristic flow pulsation of a vane pump with flow controller



The recorded experimental data of the flow ripple, saved as multidimensional characteristic map, is used together with tailored physical models to compose the pump model. RohrLEx is glad that FLUIDON provides all the test benches and equipment required to obtain the char-