Driveline and Chassis Technology

Analysis of Dynamic Pressure Puild-up in Twin-tube Vehicle Shock Absorbers with Respect to Vehicle Acoustics

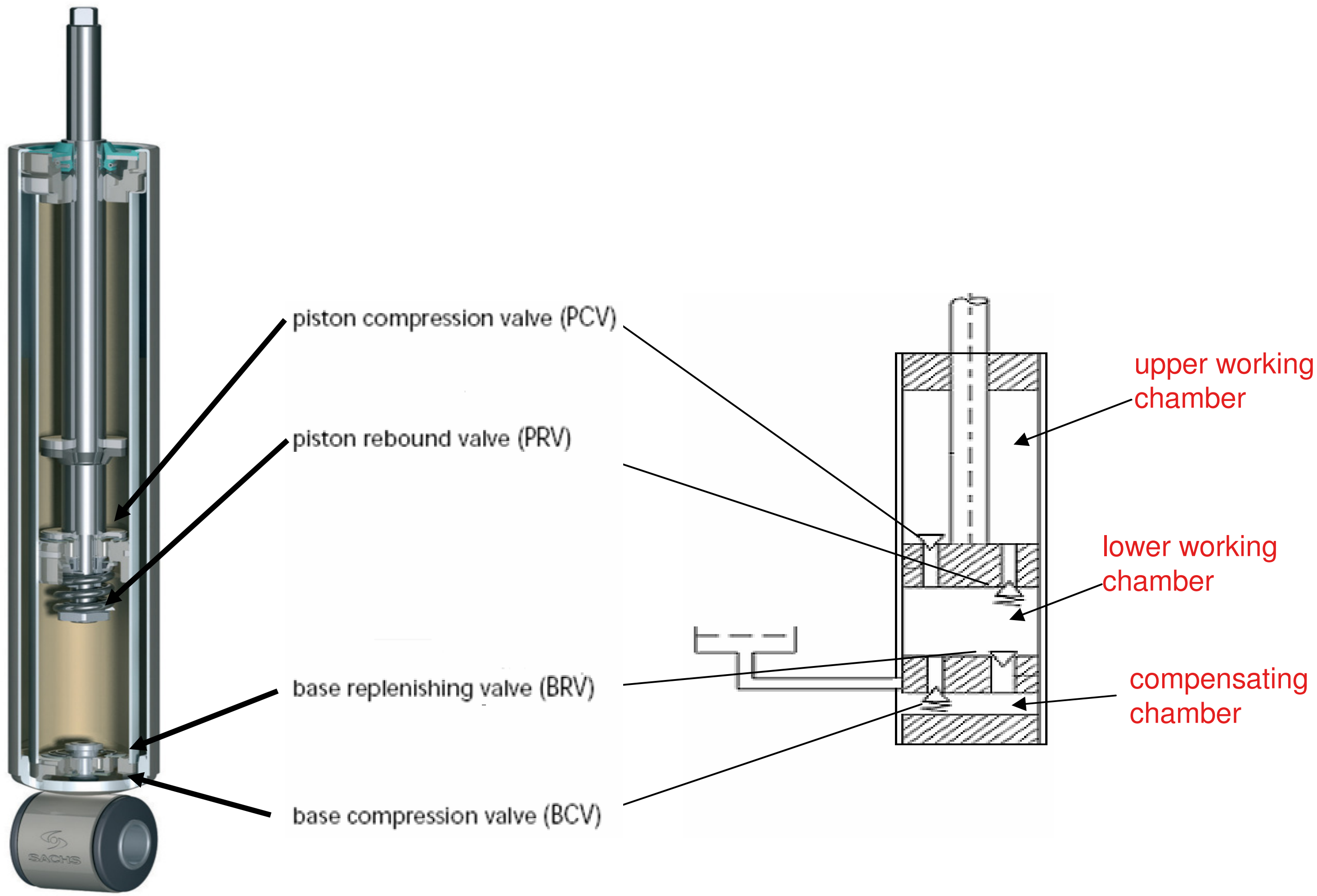
Vehicle Dynamics Expo 2008

Dr.-Ing. Alexander Kruse
ZF Sachs AG

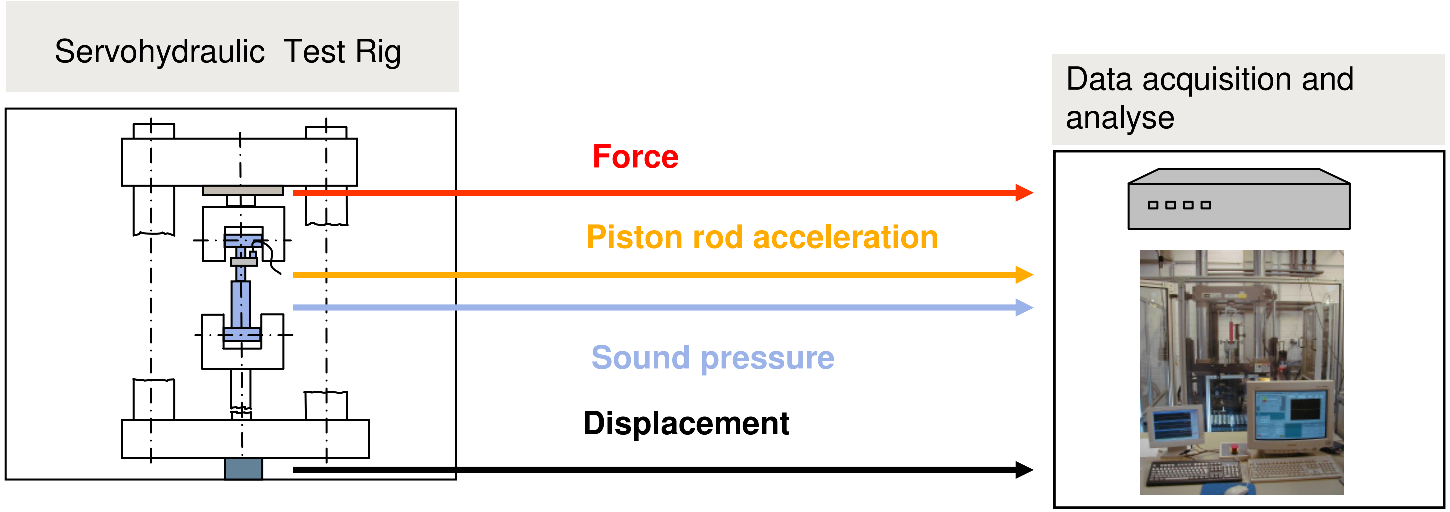
Overview

- Damping principle
- Description of processes in shock absorber valves
- Vibration analysis of shock absorber hydraulics
- Optimization of the dynamic vibration behavior
- Summary

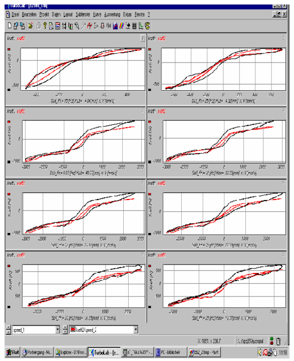
Damping principle of a twin-tube shock absorber



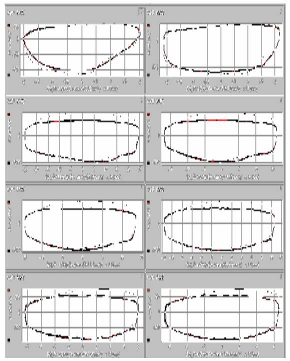
Damper Measuring at the Test Rig



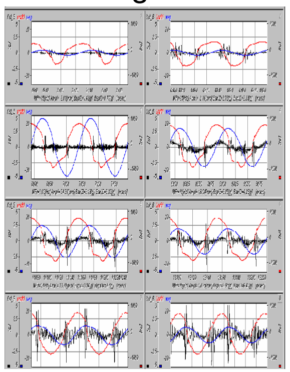
F/v **diagram**



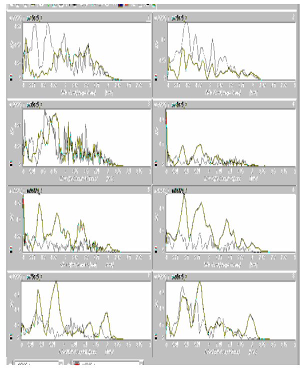
F/s **diagram**



Force, displacement, piston rod acceleration diagram

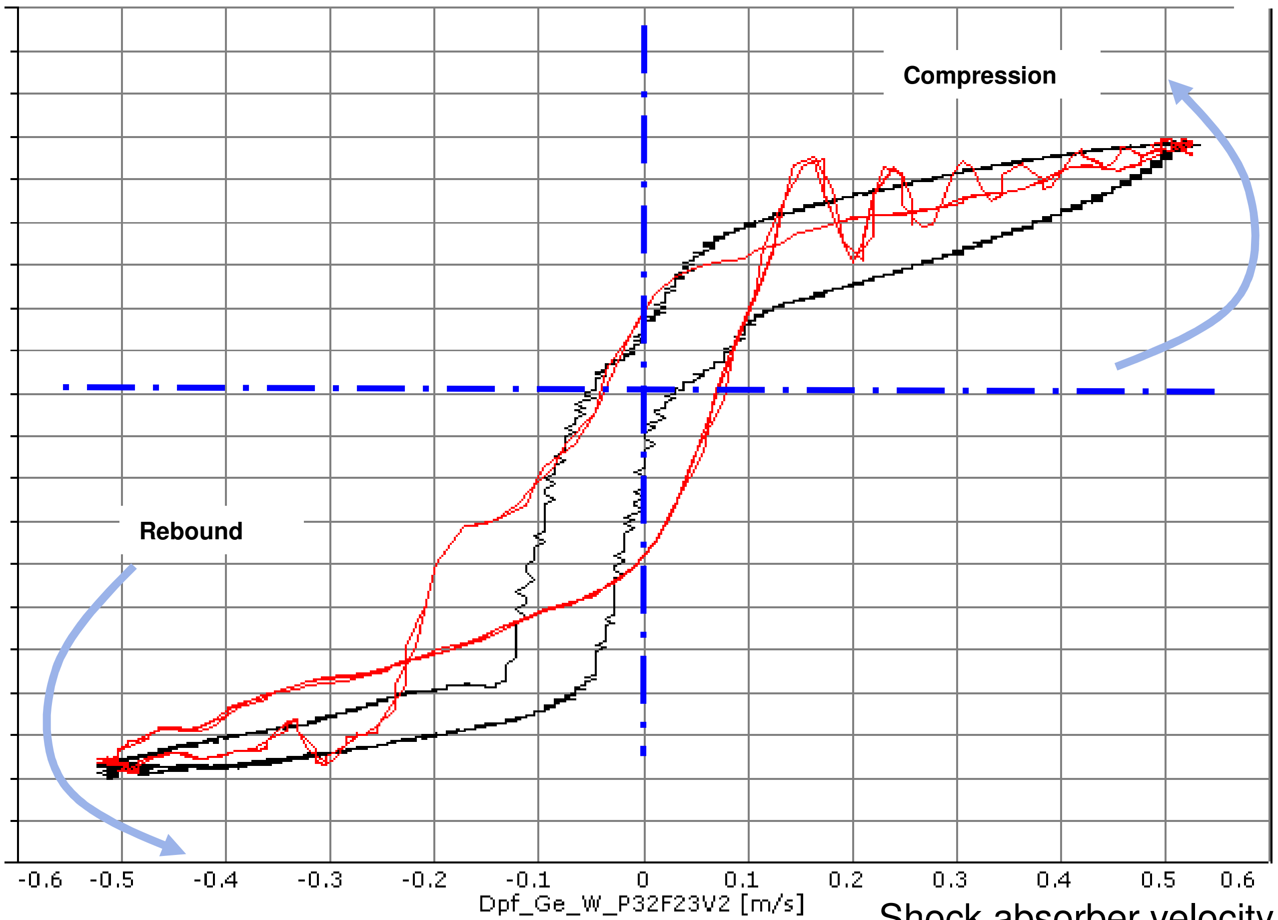


Frequency spectrum of piston rod acceleration



Comparison of *F/v* diagrams of shock absorber statically "– „dynamically"

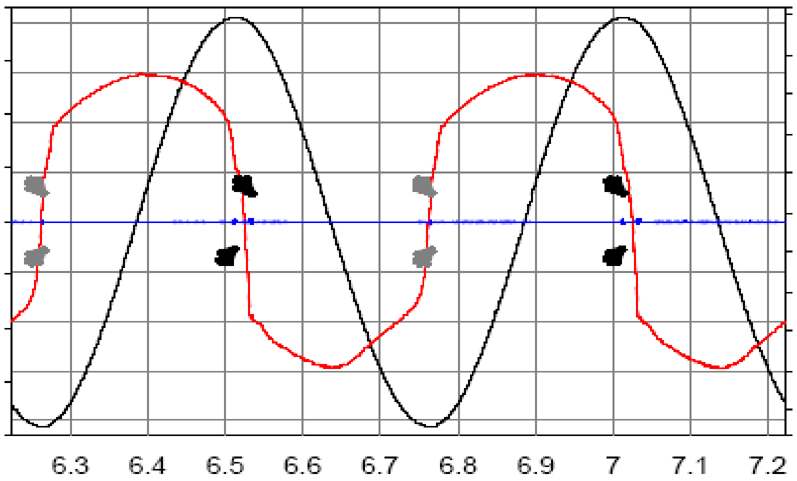
Excitation **2 Hz, 41mm, 0.5m/s** Excitation **25 Hz, 3,3mm, 0.5m/s**



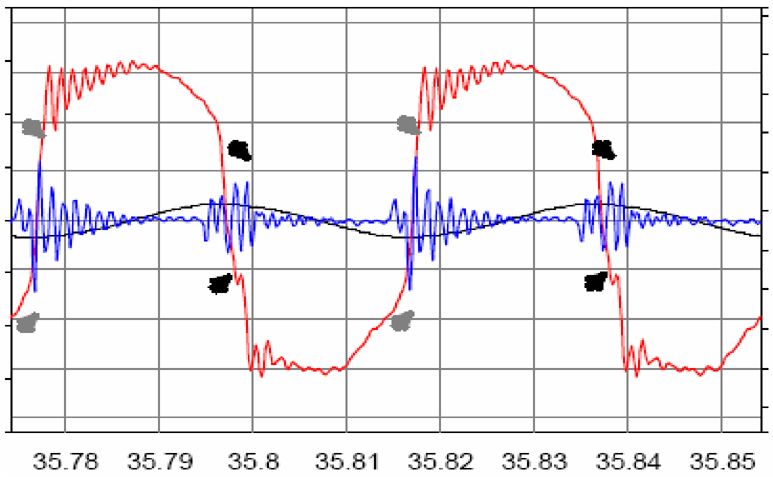
Shock absorber velocity

Damper Measuring at the Test Rig

Excitation **0.5m/s (2 Hz, 41mm)**



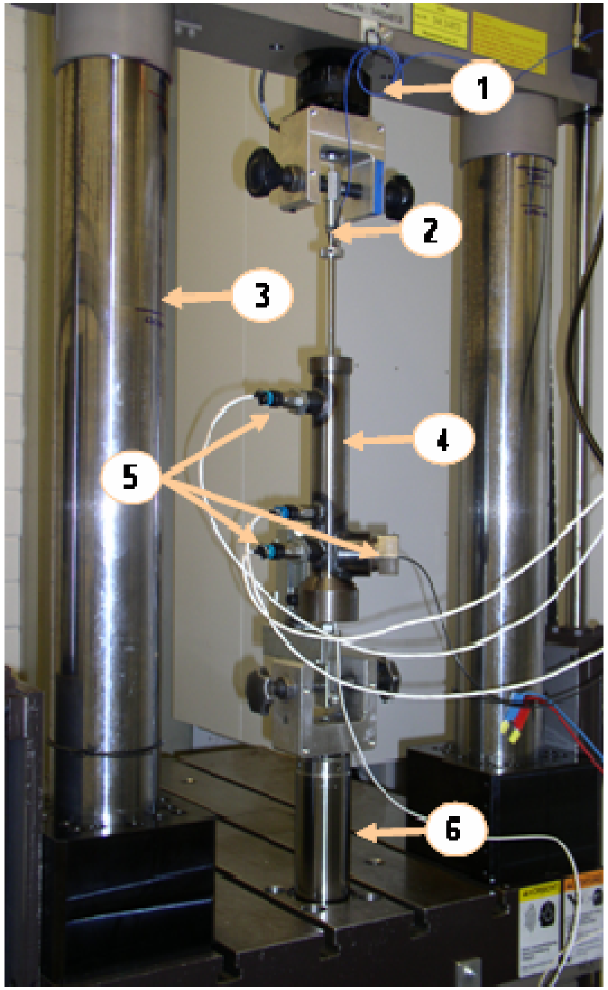
Excitation **0.5m/s (25 Hz, 3,3mm)**



- Shock absorber displacement
- Damping force
- Piston rod acceleration

Highly dynamic excitation brings significant differences to the described "quasi-static" behavior of the shock absorber

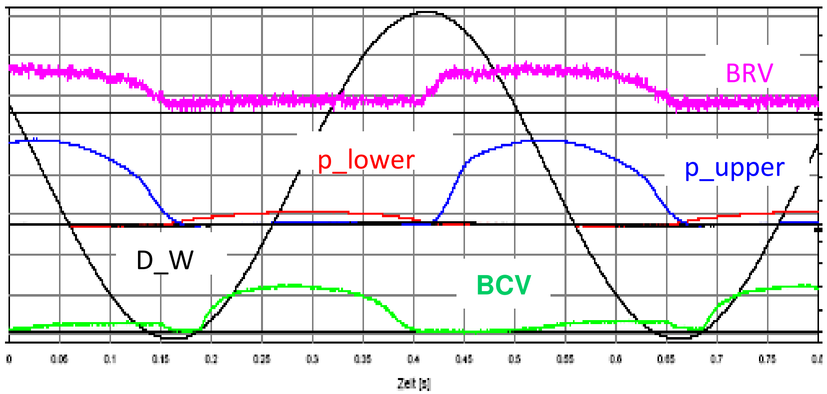
Test arrangement on rig

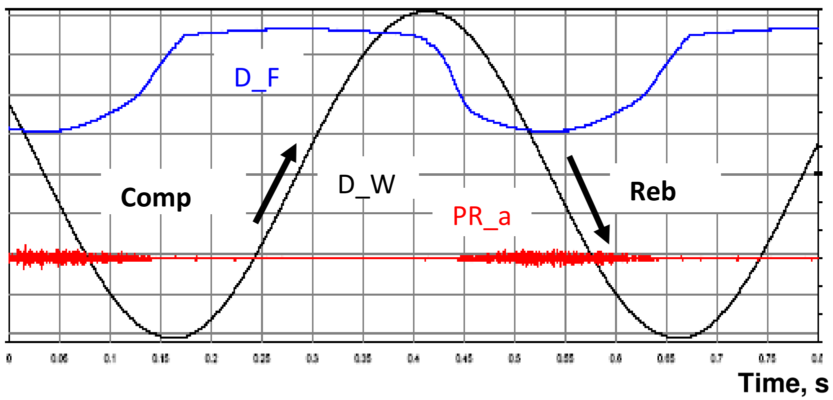


1	Load cell
2	Acceleration sensor
3	Test rig frame
4	Shock absorber
5	Sensors
6	Test rig actuator

“Quasi-static" behavior of the shock absorber

Measuring signals at excitation of 2 Hz and velocity of 1,0 m/s



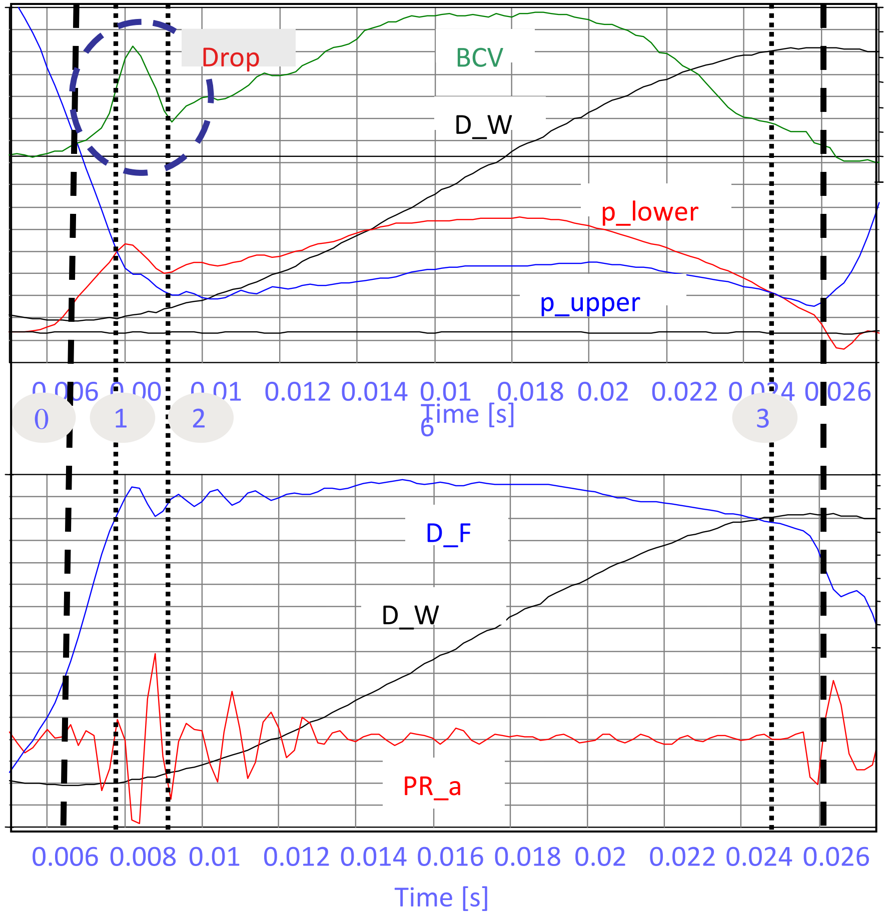


D_W	- shock absorber displacement
D_F	- damping force
PR_a	- piston rod acceleration
p_upper	- oil pressure in upper working chamber
p_lower	- oil pressure in lower workingchamber
p_ausgl	- oil pressure in compensatingchamber
BRV	- lift of base replenishing valve
BCV	- lift of base compression valve

The processes occurring in the shock absorber correspond to classic concepts. Piston and base valves open at the defined shock absorber design speed (0.2 – 0.3 m/s).

Measuring of damper characteristics

high-frequency excitation of 25 Hz and a shock absorber velocity of 1,0 m/s

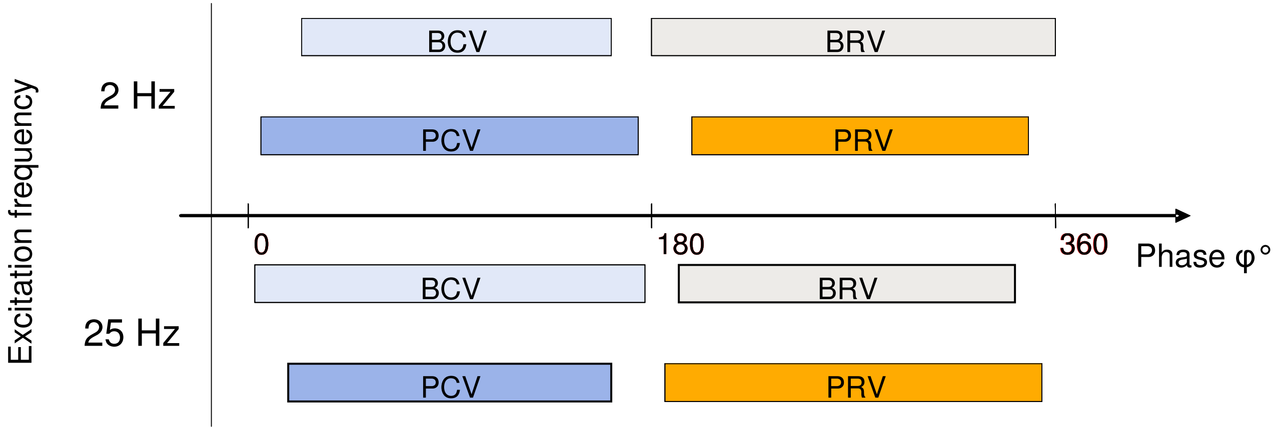


D_W - shock absorber displacement
D_F - damping force
PR_a - piston rod acceleration,
p_upper - oil pressure in upper working chamber
p_lower - oil pressure in lower working chamber
p_ausgl - oil pressure in compensating chamber
BRV - lift of base replenishing valve
BCV - lift of base compression valve

With high-frequency excitation, both working chambers are under far greater hydraulic pressure at the reversal point than with slow excitation. The maximum damping force is reached shortly after the start of the compression stage.

Valve opening phases

"quasi-static" and highly dynamic shock absorber excitation



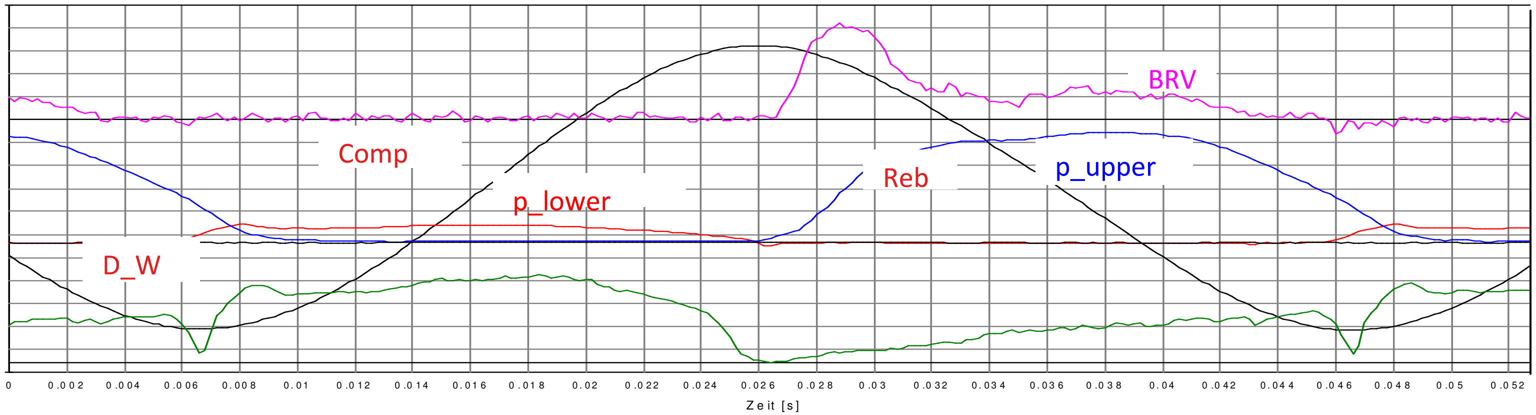
High-frequency excitation causes a length reduction of the opening time in the case of check valves (delay on opening and premature closing) and extension of the opening time (delay on closing and premature opening) of the main valves

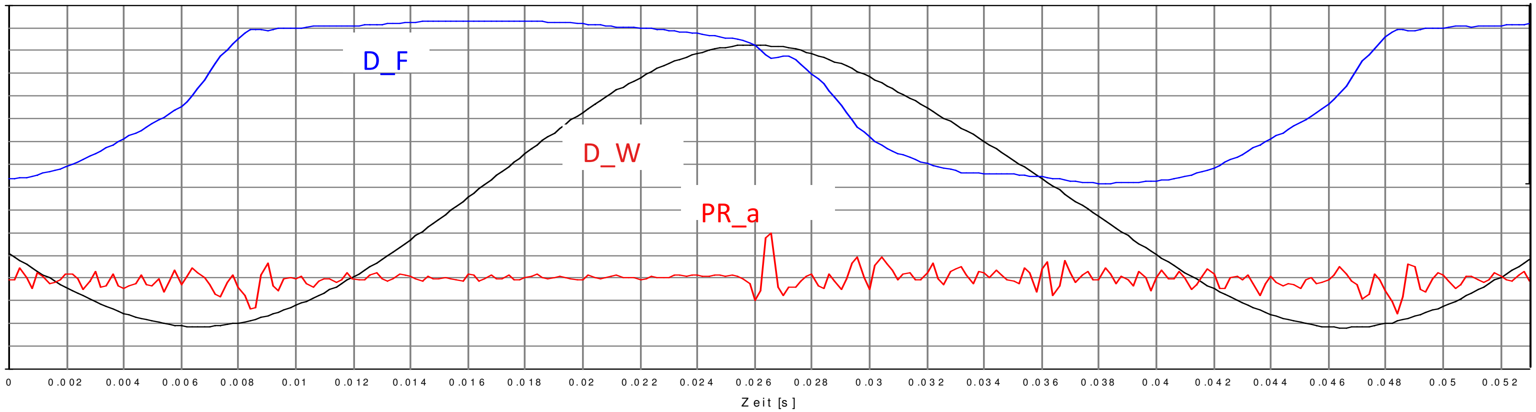
Excitation frequency, Hz	Ratio $p_{upper\ chamber}/p_{lower\ chamber}$		Phase φ at maximum damping force	
	φ= 0°	φ= 180°	Compression	Rebound
2	1.5	1.0	90°	270°
25	8	3	20°	290°

These phase shift cause problems in harmonic pressure and force build-up

Measuring characteristics of modified shock absorber setting

high-frequency excitation of 25Hz and a shock absorber velocity of 1 m/s





Significant improvement of vibration behaviour, through elimination of pressure retention at modified setting

Summary

- Analysis of the dynamic vibration processes going on in the working chambers showed that the damping force irregularities and noise occur at the start of valve opening

- Improvement of dynamic pressure build-up through valve optimization brought distinct noise reduction

- With knowledge of the valve operating characteristics in conjunction with the internal pressure characteristics, effective optimization strategies can be pursued

Thank you very much for your attention!