Simulation based Power Steering Hose Design and Optimization

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COMPETENCE IN FLUID POWER SYSTEMS SIMULATION
KOMPETENZ IN DER SIMULATION FLUIDTECHNISCHER SYSTEME

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Gesellschaft für Fluidtechnik mbH

FLUIDON a spin-off of the RWTH Aachen

Institut für fluidtechnische Antriebe und Steuerungen RWTH

IFAS, Expansion Building and Conference Room

Areal View of IFAS

Historical Highlights of IFAS - Institute for Fluid Power Drives and Controls

As nationally and internationally recognized research institution, the IFAS is and has been pioneering many developments in Fluid Power technology.

60's: Beginnings of servo hydraulics, fluidics

70's: Basis of cavitation research, servo pneumatics, pump controlled systems

80's: Digital control, development of DSH*plus* (simulation tool), proportional / directional control cartridge valves, secondary control

90's: Pre-compression chamber in piston pumps, fuzzy control, bio fluids, piezo technology, sealing engineering (blow-by effect)

present: Coating technology, condition monitoring

The Institute's Development

1968: IFAS is founded as "Institut für hydraulische und pneumatische Antriebe und Steuerungen" - IHP in short. Under Professor Backé's direction, two academic and six non-academic staff members are employed in the very beginning.

1977: The Institute now moves into its own large experimental hall with attached office building in the RWTH Expansion Area Seffent-Melaten. Now, there is room for about 50 test-stands, workshops, laboratories, computer rooms and a library.

1994: Concurring with the succession to the direction of the Institute and to the professorship by Professor Murrenhoff is the change of the Institute's name. Today, about 25 academic staff members, 20 non-academic employees and approx. 40 student assistants are working under the grammalogue IFAS. **Founding of FLUIDON as Spin-Off**

1998: Opening of the expansion building which offers additional space for offices as well as computer, seminar and conference rooms thus giving more capacity for R&D tasks.

Laboratory and test rig recourses at IFAS

IFAS disposes two experimental laboratory buildings which are equipped with workshops and laboratories and give excellent opportunities to deal effectively with R&D tasks. The newest measuring technology for all fluid power values is available.

- floor space about 1250 m² room for approx. 60 test rigs
- 2 clamping beds (5 x 3m), 70 ton foundation, 2 clamping beds (3 x 2.5m)
- 5 sound proof closets, 35 ton foundations
- anechoic room for sound measurements, (6.5 x 8m), drives 200 kW
- passable climatic test room (4.75 x 3.3 x 3m), -70℃ to +70℃, 20% to 95% relative humidity
- valve test stand max. 315 bar
- max. 500 1/min. ageing test rigs for hydraulic fluids tribo tester

Laboratory Building 2

Laboratory Buildings 1

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Thematic introduction

- The inside noise level of a vehicle represents an essential decision feature for the purchase decision of the customer. To satisfy this consumer expectation, it is nowadays extremely important that a potential source of noise, vibration or harshness (NVH) is identified and eliminated as early as possible in the development process.

- A known source for noise which can lead to NVH problems within the vehicle is the fluid-borne noise, issued by the pump of the hydraulic power steering. Currently the design and optimization of power steering hoses is mainly done by costly hardware tests.

- The adaptation of the automotive hose lines requires a high effort since hardware prototypes are optimized up to the desired maturity degree by means of test rig or vehicle tests. Without the amplified use of CAE tools a cost optimal development on schedule of new automotive hose lines in future can be only handled with difficulty.

- What was missing till now, for a time-domaine-based simulation, were suitable models for the flexible hose parts. As a result of the cooperation of FLUIDON GmbH and a manufacturer of automotive hoses these models are available now and a simulation-based development methodology for automotive lines can be presented.

Simplified consideration of hose wall compliance

Vereinfachte Berücksichtigung der Schlauchwandnachgiebigkeit

1. The combination of rubber material and cord netting of the hose is responsible for a viscous-elastic behavior that determinates its damping characteristics (Figure 1).

2. The reinforcement material has either a more linear (steel braiding) or viscous-elastic (polyamid yarn) behavior. Due to the relative movement between the reinforcement layers there is moreover a static friction (coulomb friction) in the hose sleeve, which affects the damping characteristics as well.
   Some literature sources propose linear/viscoelastic damper models that are in a series connection to represent the reinforcement layers (Figure 2).

3. Up to now there is no physical model available that describes such behavior. However there are some approaches available that use measured material properties for simplified replacement models (Figure 3).

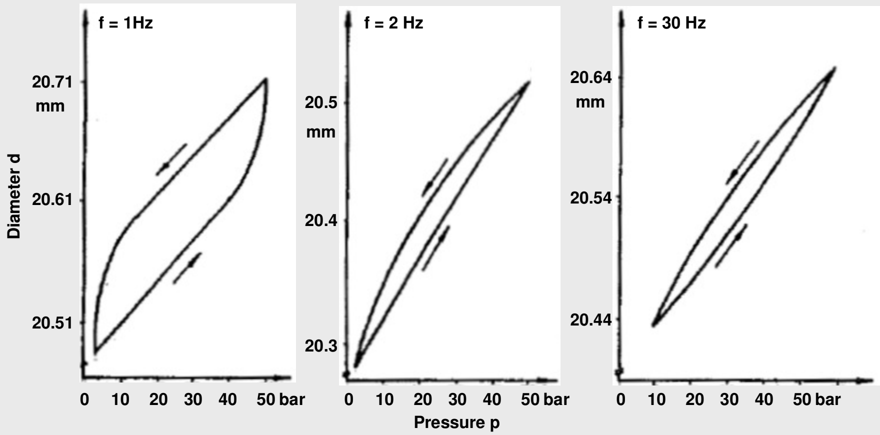


Figure 1

Hose Wall Dynamic at 1Hz, 2Hz, and 30 Hz
(Diss Sänger, IHP, Aachen, 1985)

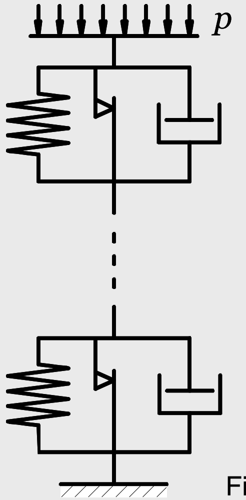


Figure 2

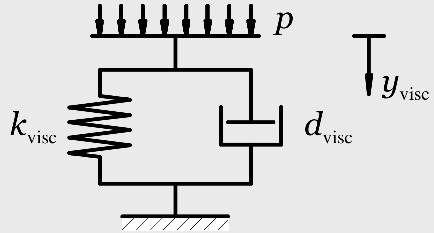
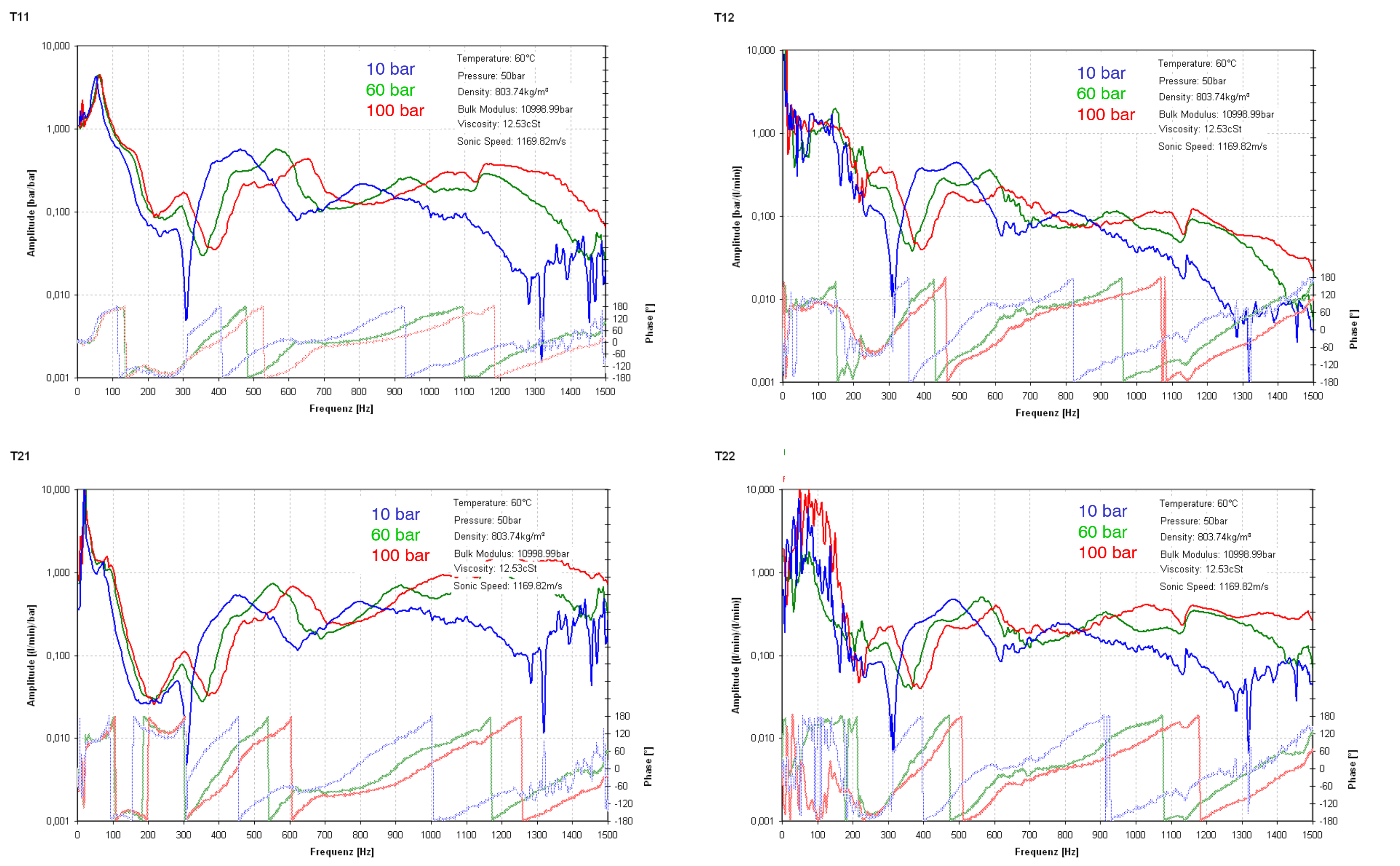


Figure 3

Pressure variation of an one-chamber hose line at 60 ℃

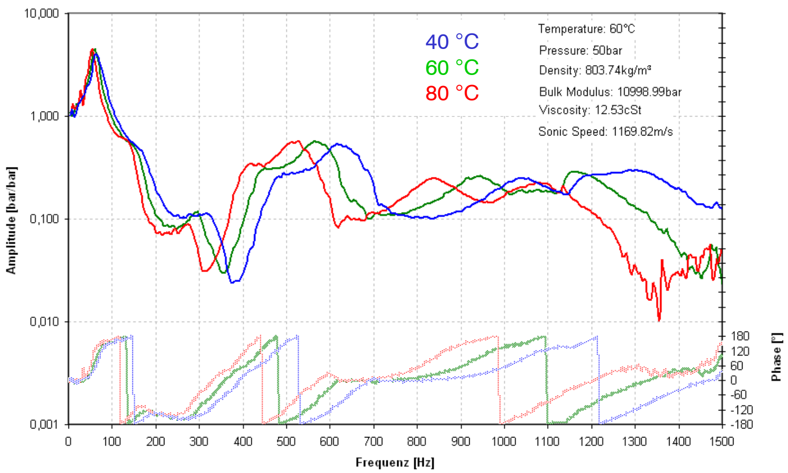
Druckvariation einer Ein-Kammer-Schlauchleitung bei 60 ℃



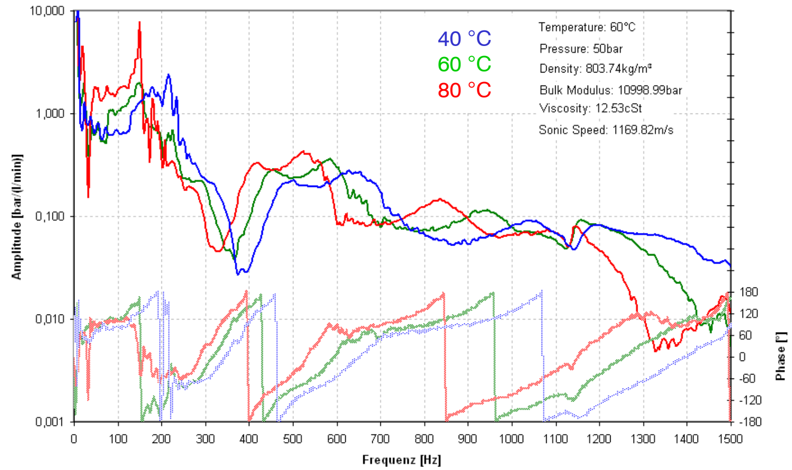
Temperature variation of an one-chamber hose line at 50 bar

Temperaturvariation einer Ein-Kammer-Schlauchleitung bei 50 bar

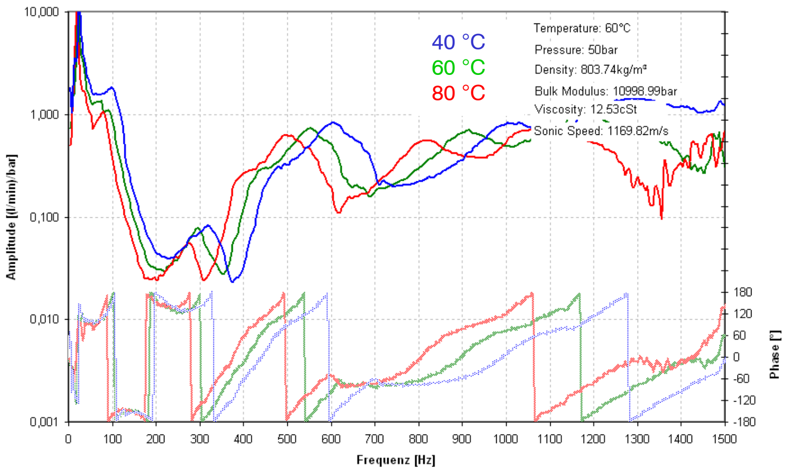
T11



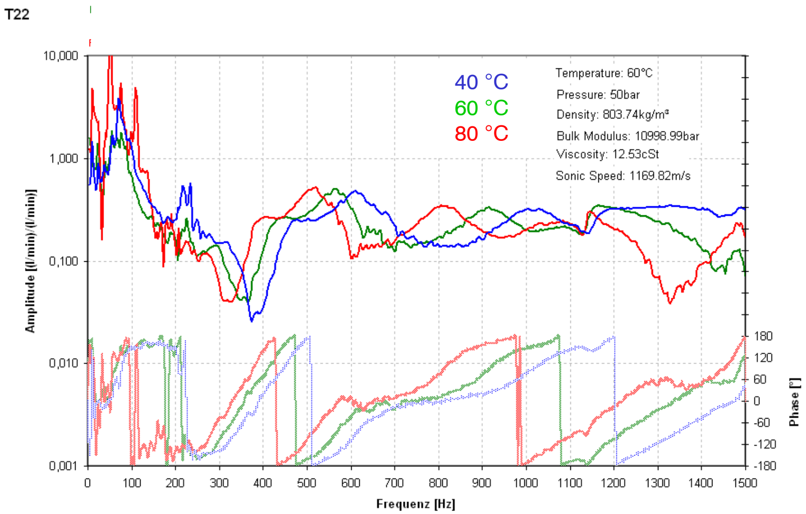
T12



T21



T22



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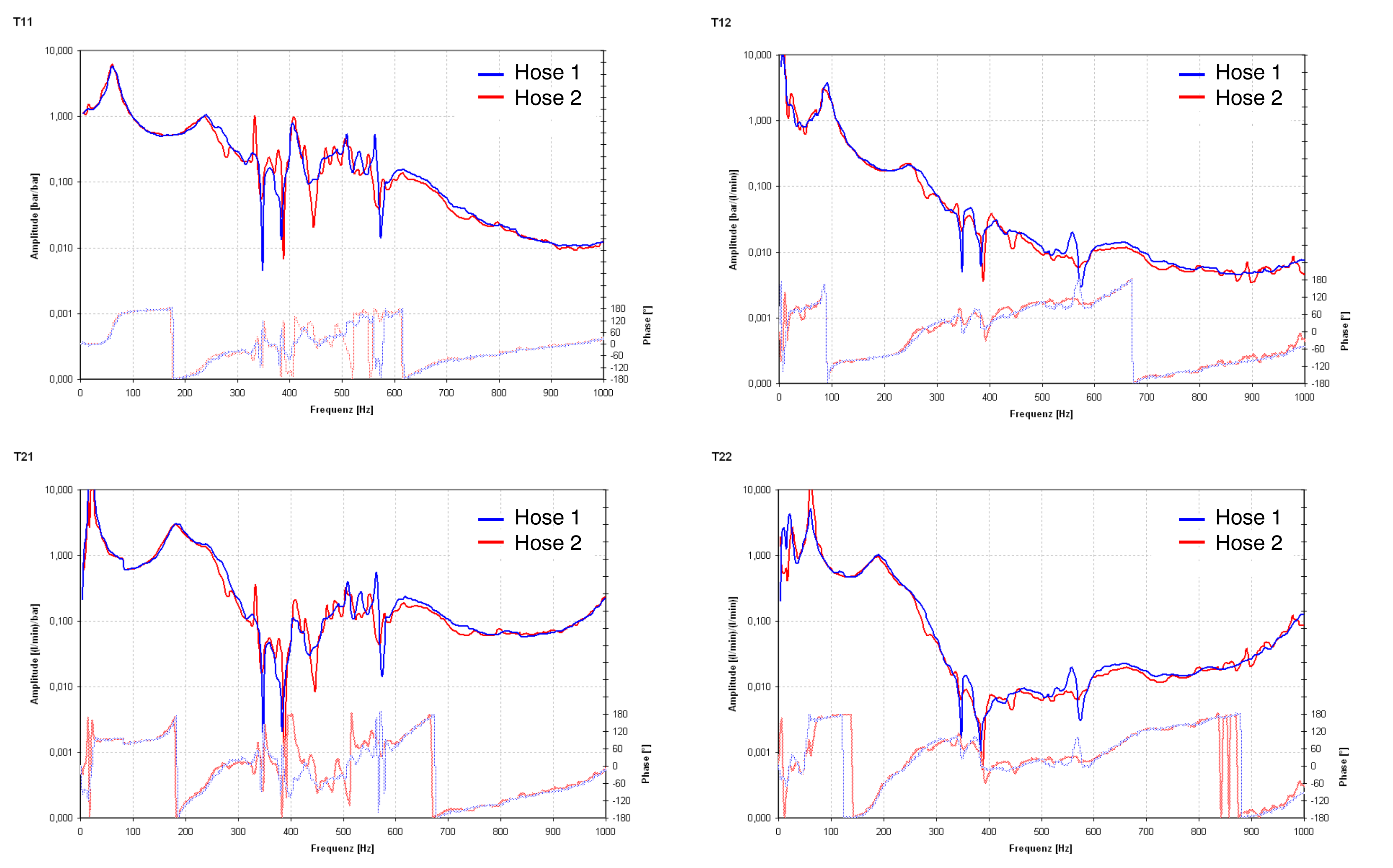
Fingerprint of an one-chamber line at 50 bar – 60 °C

Vergleich zweier Ein-Kammer-Leitungen bei 50 bar – 60 °C



Fingerprint of a two-chamber line at 10 bar - 40 °C

Vergleich zweier Zwei-Kammer-Leitungen bei 10 bar und 40 °C

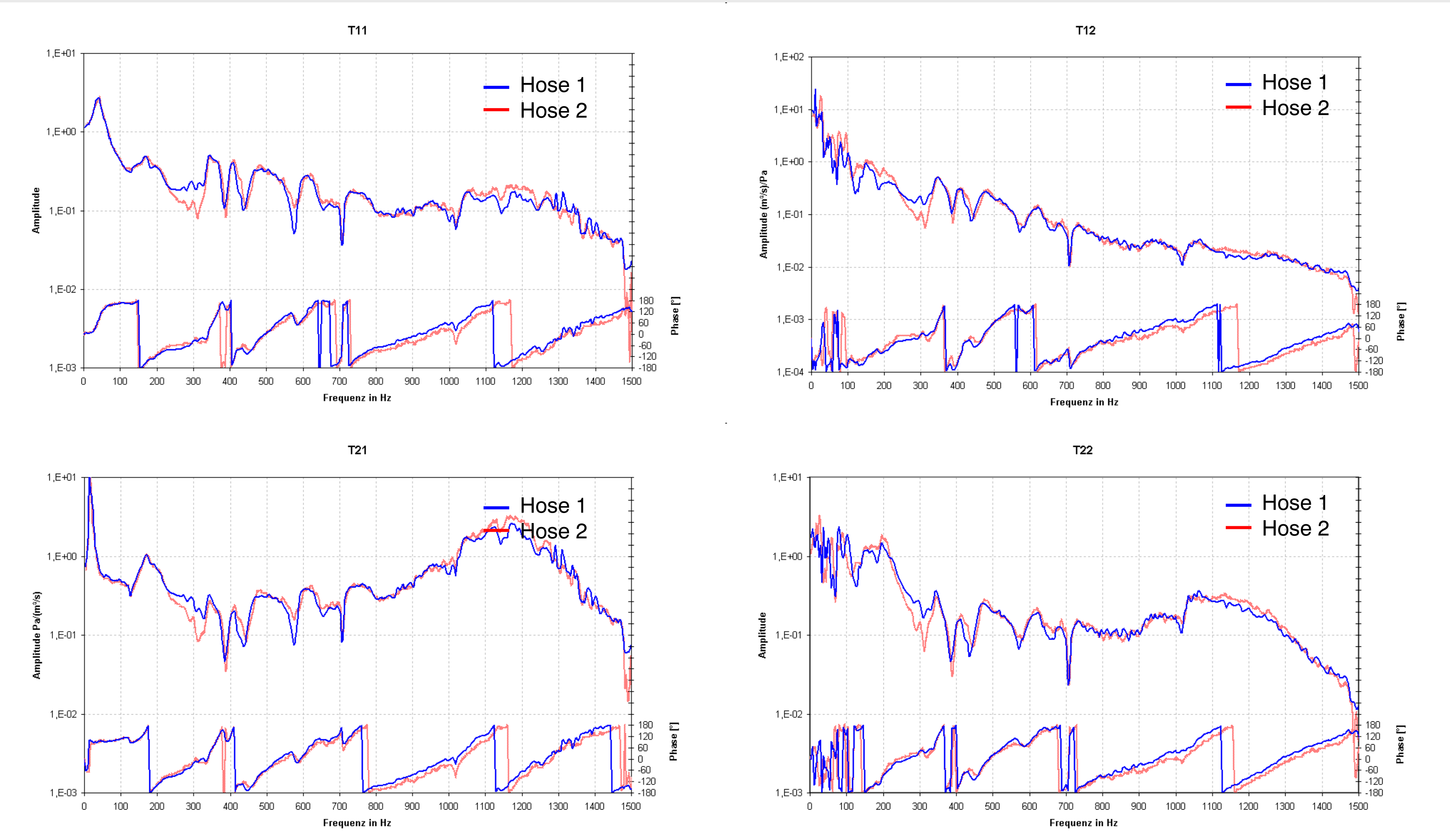


Figure 11
Vehicle Dynamics 2008

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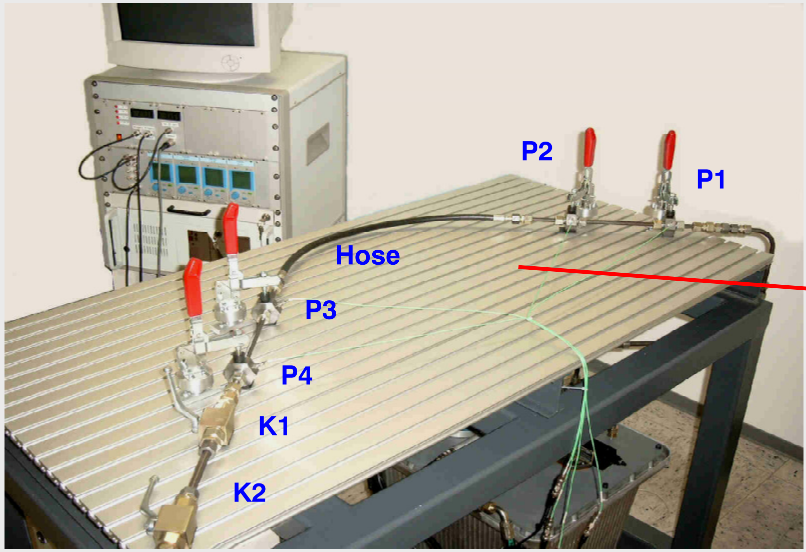
Identification of hose material characteristic

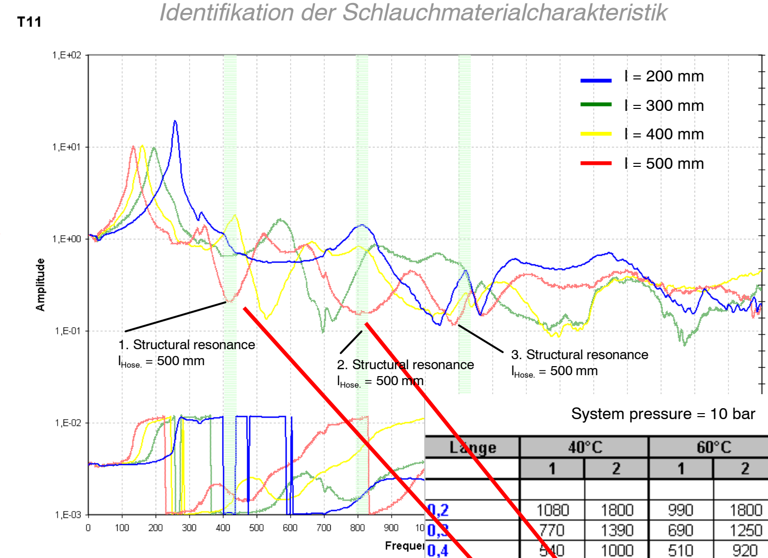
Identifikation der Schlauchleitungscharakteristik



1. Test rig measurements:
   Variation of hose length from 100 mm to 500 mm.
   Each hose at 40, 60, 80°C and at 10, 50, 100 bar
   Prüfstandsmessungen: Variation der Schlauchlänge von 100 mm bis 500 mm. Jeder Schlauch bei 40, 60, 80 °C und bei 10, 50, 100 bar

2. Identification of Hose Material Characteristic

Identifikation der Schlauchmaterialcharakteristik



System pressure = 10 bar

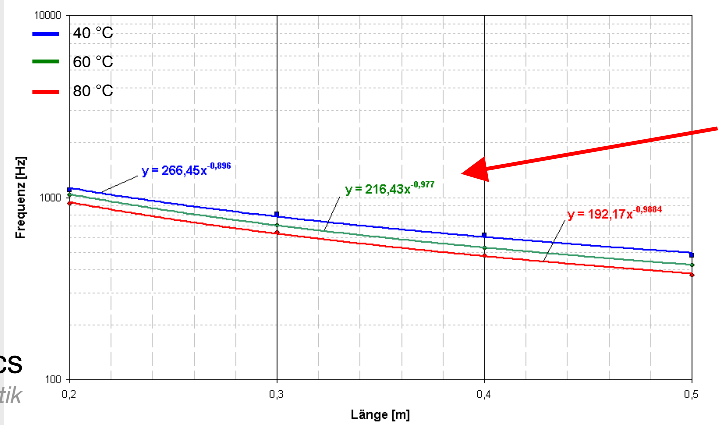
Länge	40°C		60°C		80°C	
	1	2	1	2	1	2
0,2	1080	1800	990	1800	890	1480
0,3	770	1390	690	1250	620	1090
0,4	540	1000	510	920	460	830
0,5	440	815	400	750	350	660

System pressure = 50 bar

Länge	40°C		60°C		80°C	
	1	2	1	2	1	2
0,2	1100		1040	1780	930	1750
0,3	810	1490	705	1350	645	1200
0,4	620	1120	530	1010	480	920
0,5	480	890	425	820	375	810

System pressure = 100 bar

Länge	40°C		60°C		80°C	
	1	2	1	2	1	2
0,2	1270		1120		995	
0,3	850	1650	760	1500	675	1350
0,4	640	1200	575	1150	510	1030
0,5	500	990	455	910	410	820



3. Calculation of material characteristics

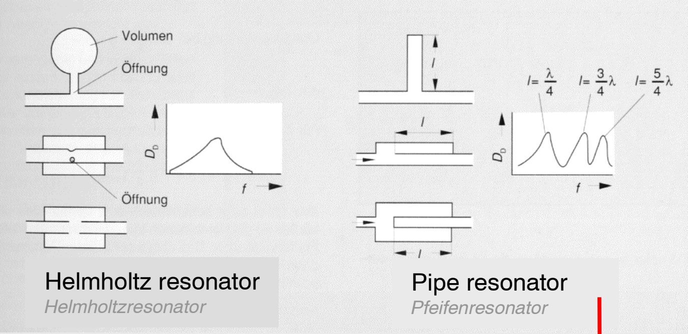
Berechnung der Materialcharakteristik

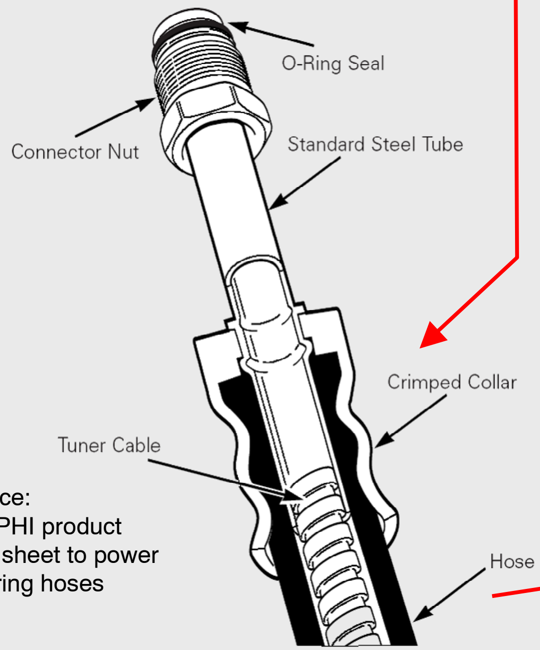
Example of a steering system model with complex feed line

Beispiel eines Lenksystemmodells mit komplexer Versorgungsleitung

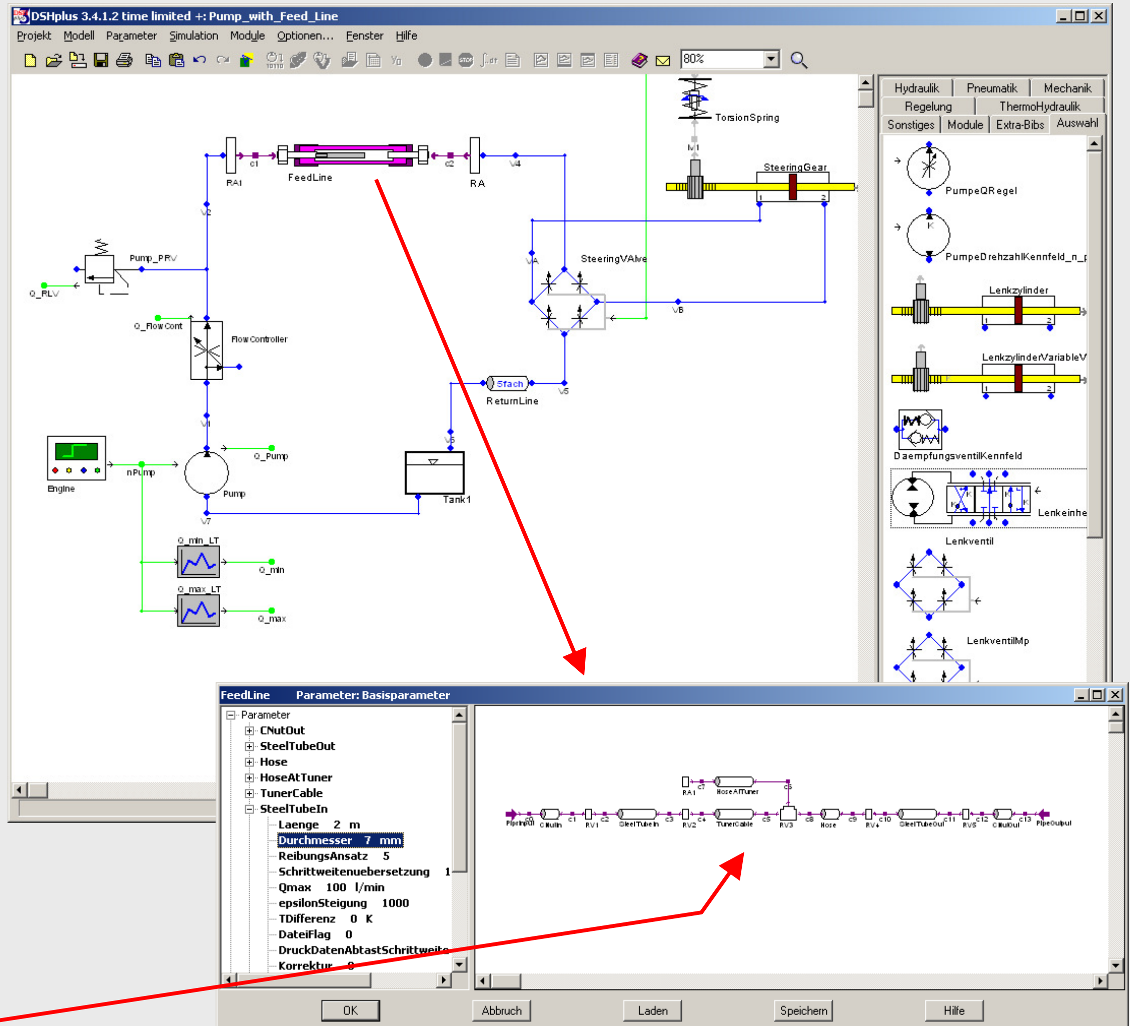
Basic resonator types

Basistypen für Resonatoren



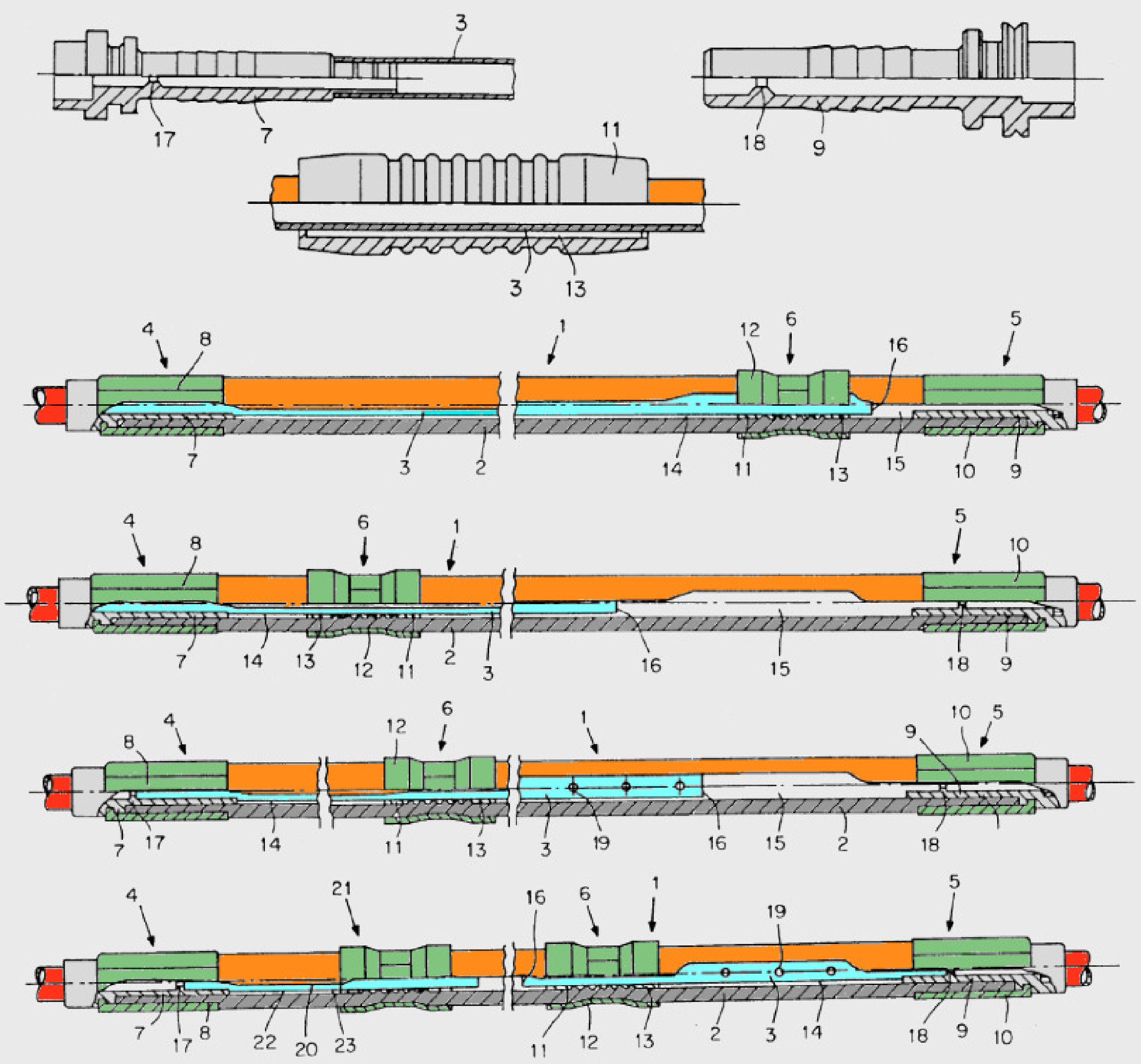


Source:
DELPHI product data sheet to power steering hoses



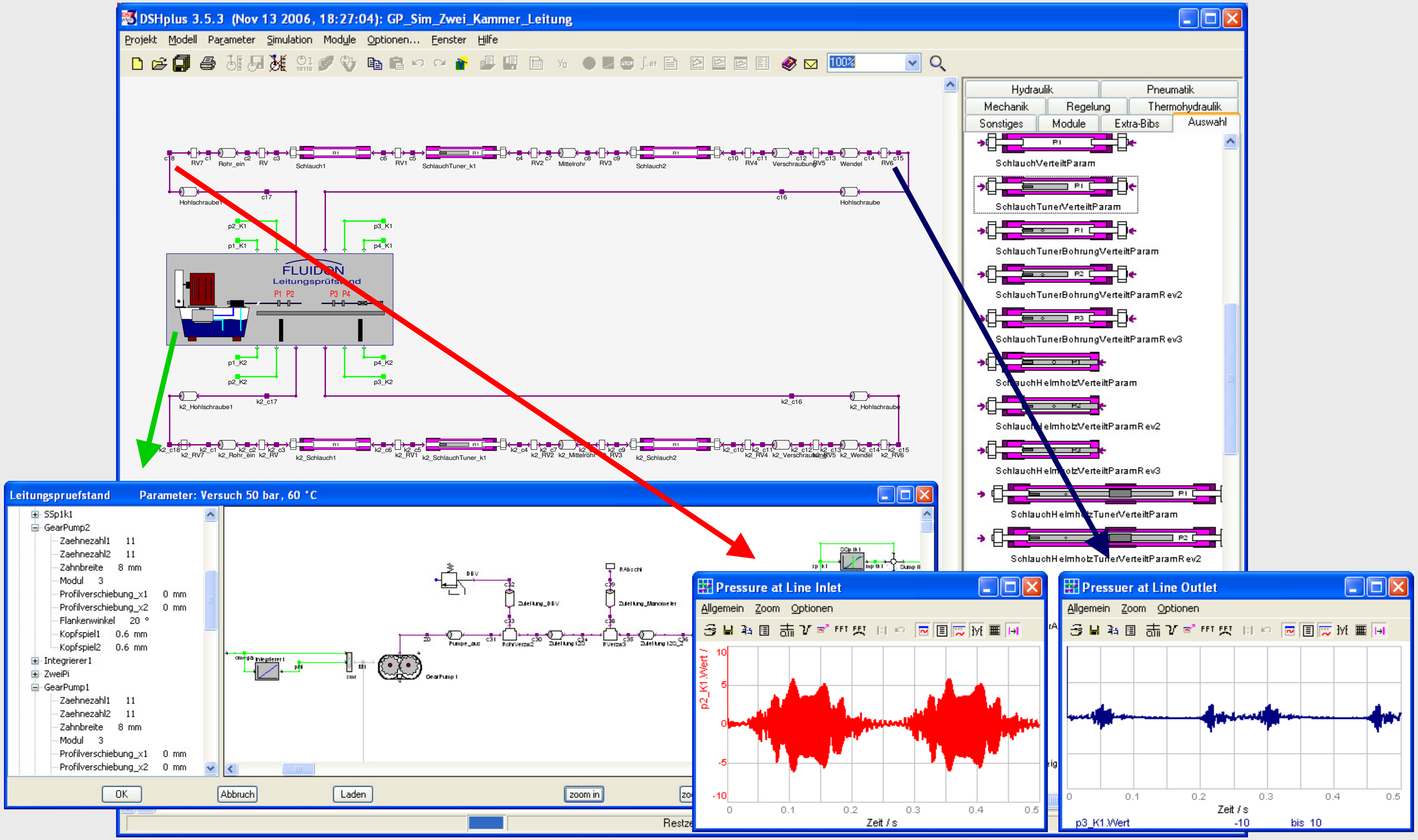
Examples for fittings and flexible hose elements

Beispiele für Installationen und flexible Schlauchelemente



Flexible hose library and simulation model of a two-chamber line

Dehnschlauchbibliothek und Simulationsmodell einer Zwei-Kammerdehnschlauchleitung



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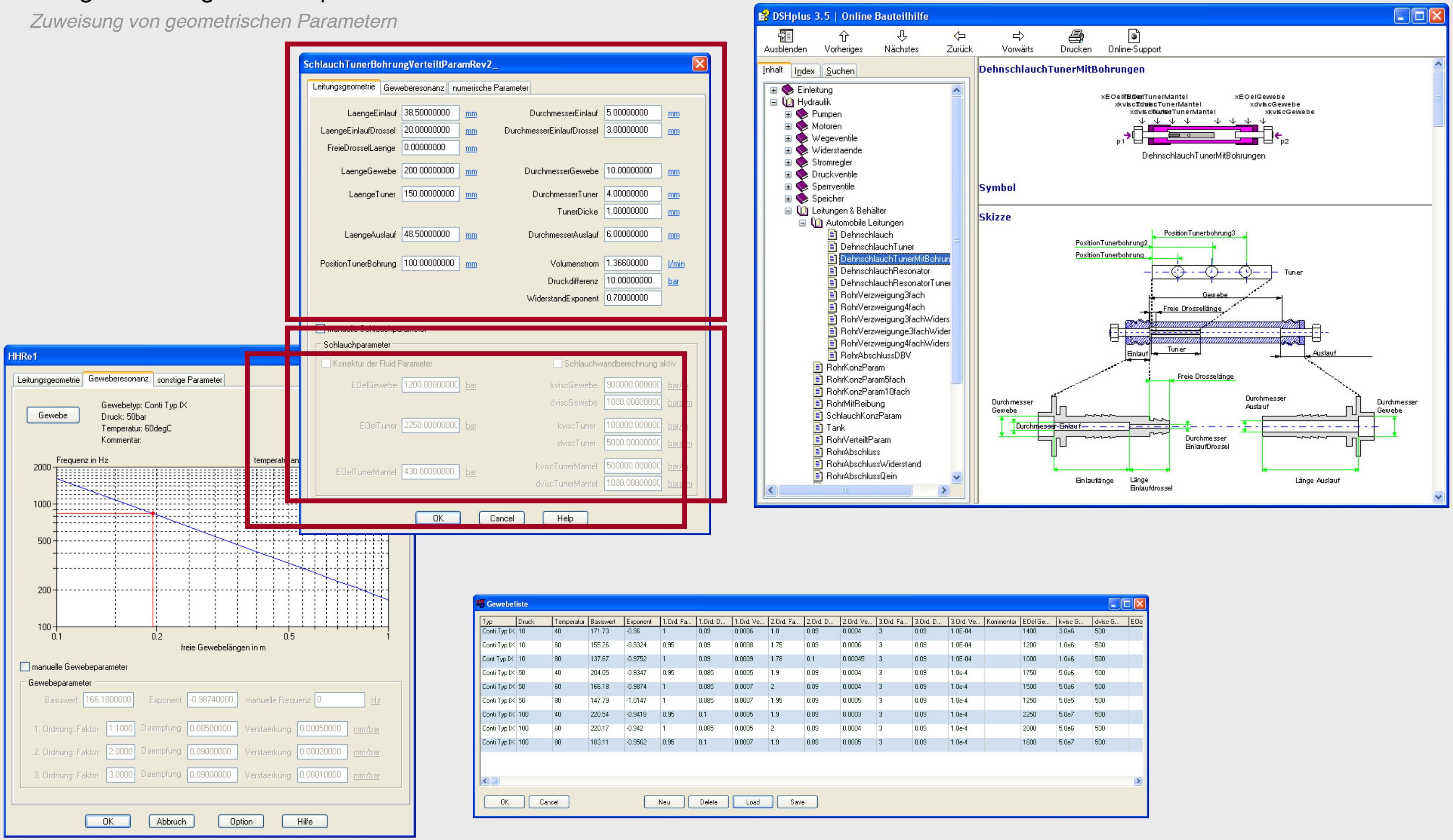
Usage of hose material characteristic

Anwendung der Schlauchleitungscharakteristik

1. Assignment of geometric parameters

Zuweisung von geometrischen Parametern



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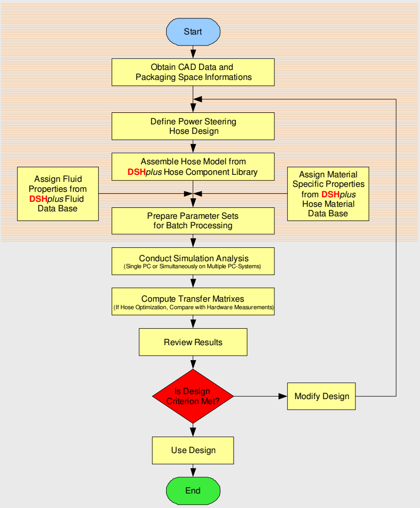
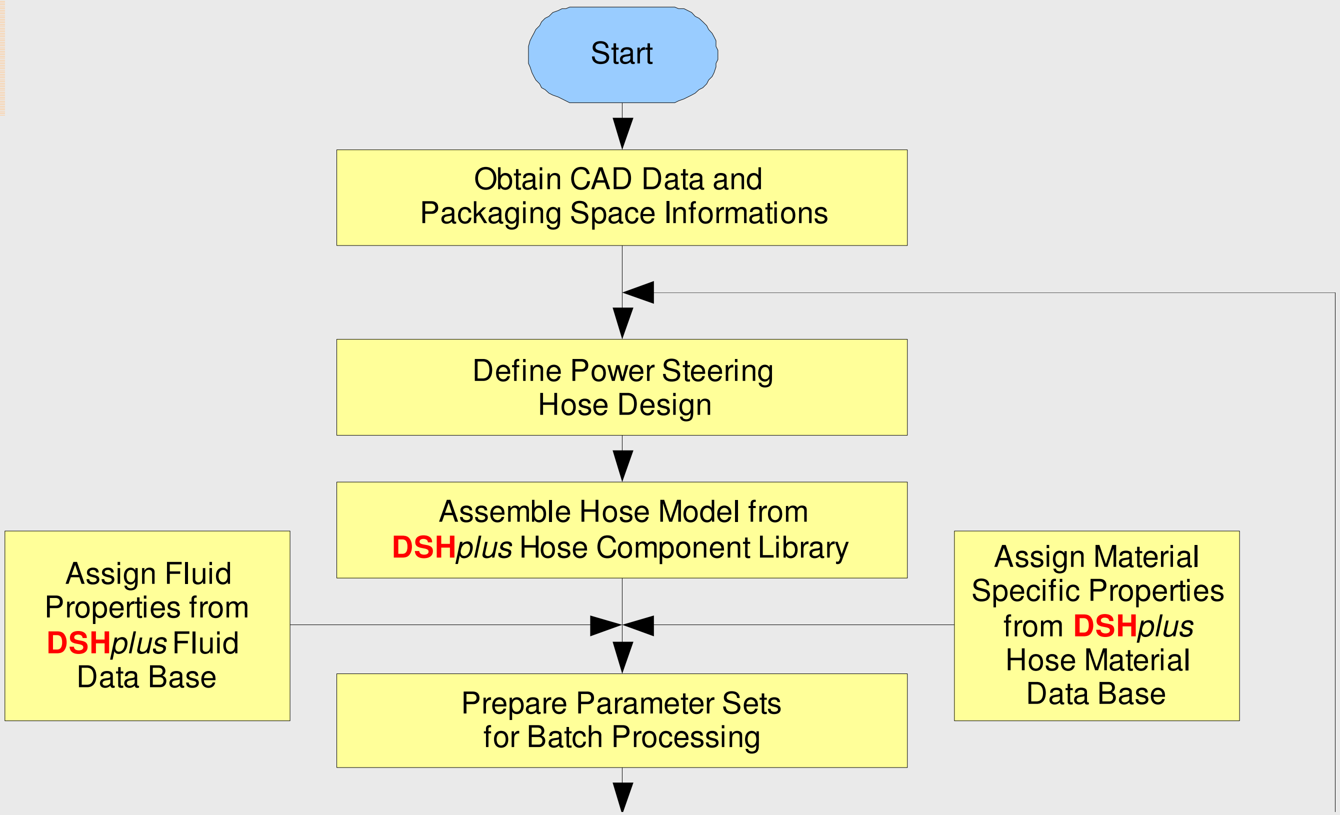
Development methodology for automotive hose assemblies

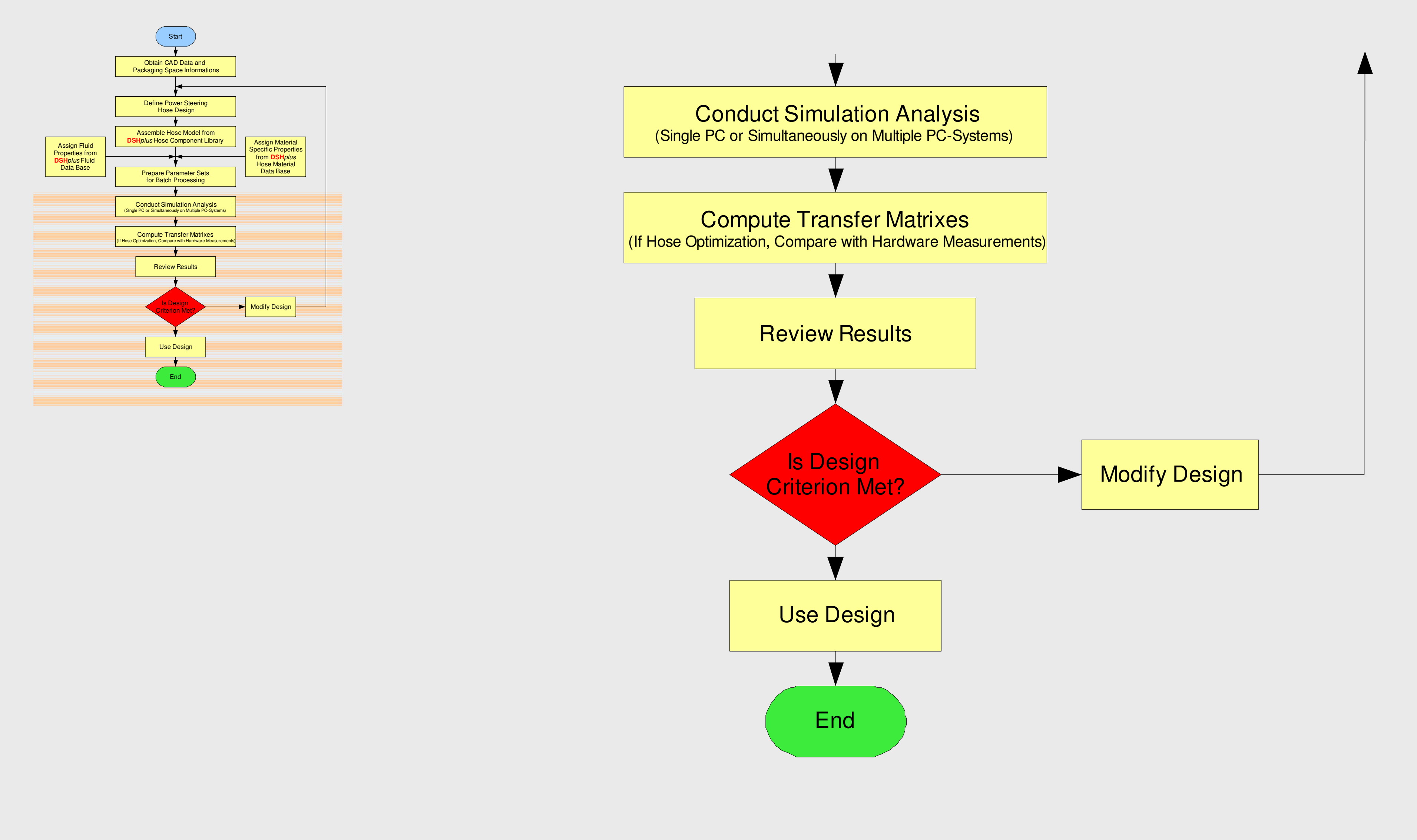
Entwicklungsmethodik für automobile Dehnschlauchleitungen





Development methodology for automotive hose assemblies

Entwicklungsmethodik für automobile Dehnschlauchleitungen



1 **Introduction**

2 Current situation of hydraulic pipe and hose simulation

3 Development of a library for flexible hose elements

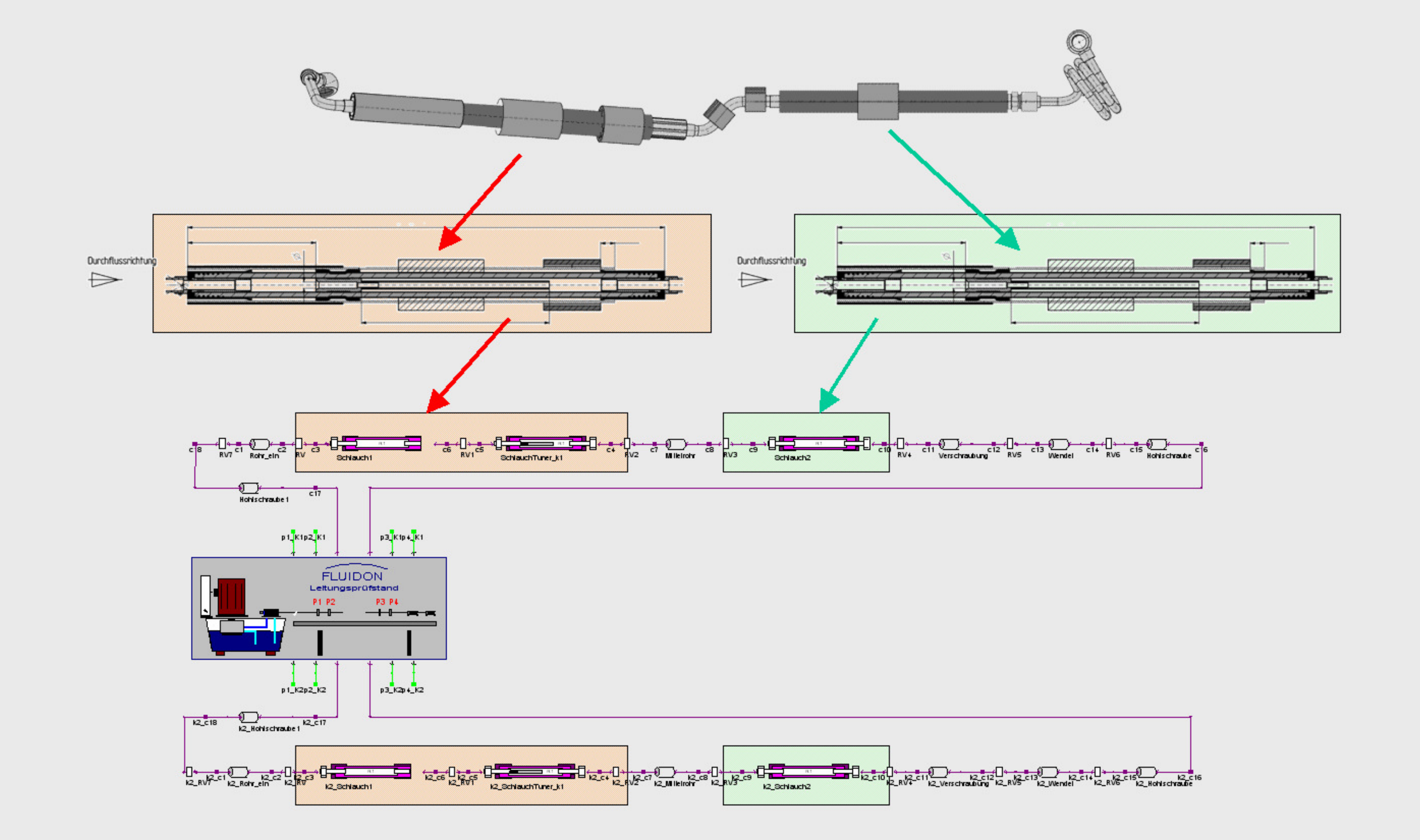
4 A development methodology for automotive lines

5 Presentation of example lines

6 Summary

Simulation model of a two-chamber line

Simulationsmodell einer Zwei-Kammer-Leitung



Example for an optimization of a two-chamber line

Beispiel für die Optimierung einer Zwei-Kammer-Leitung

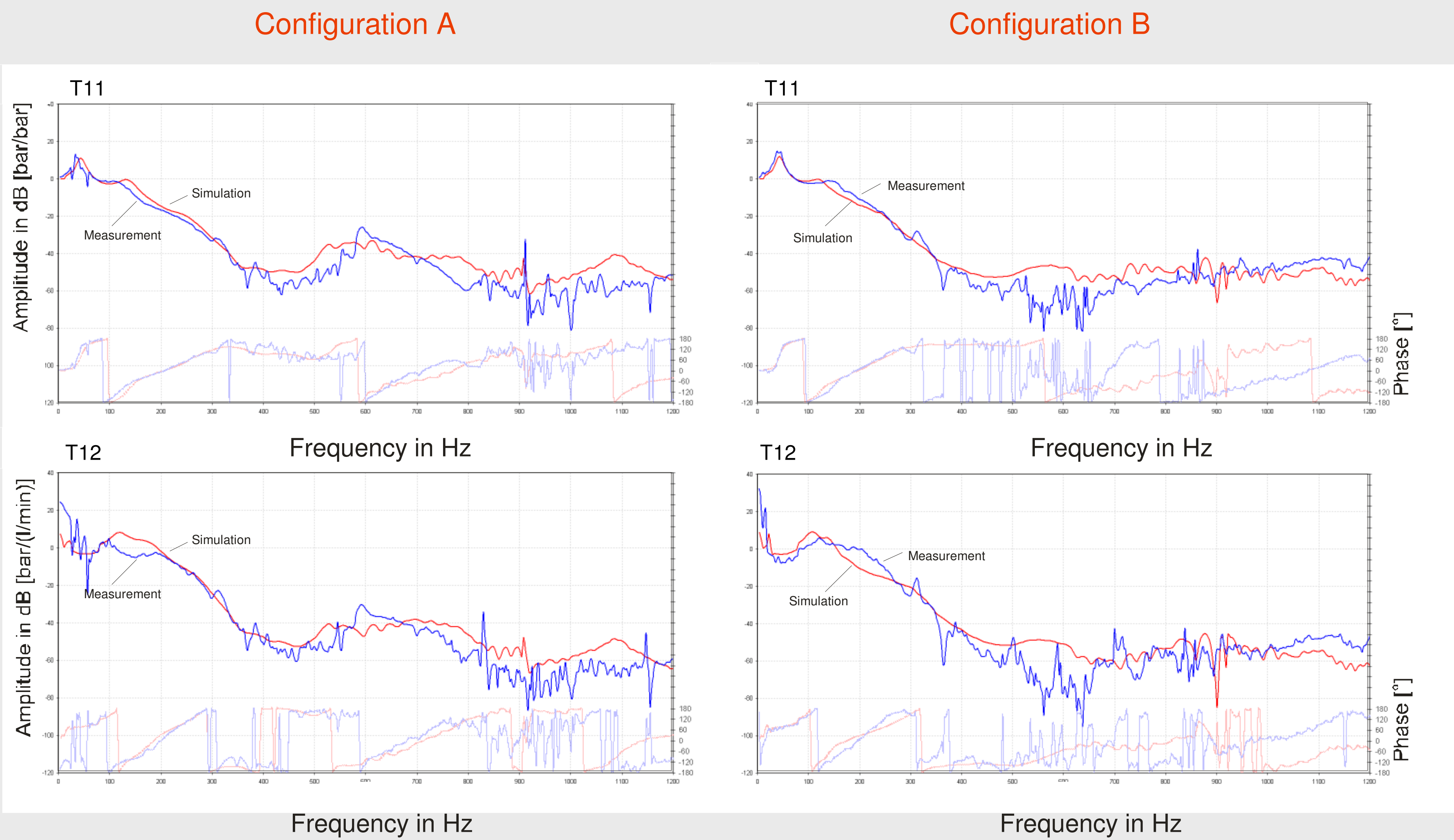
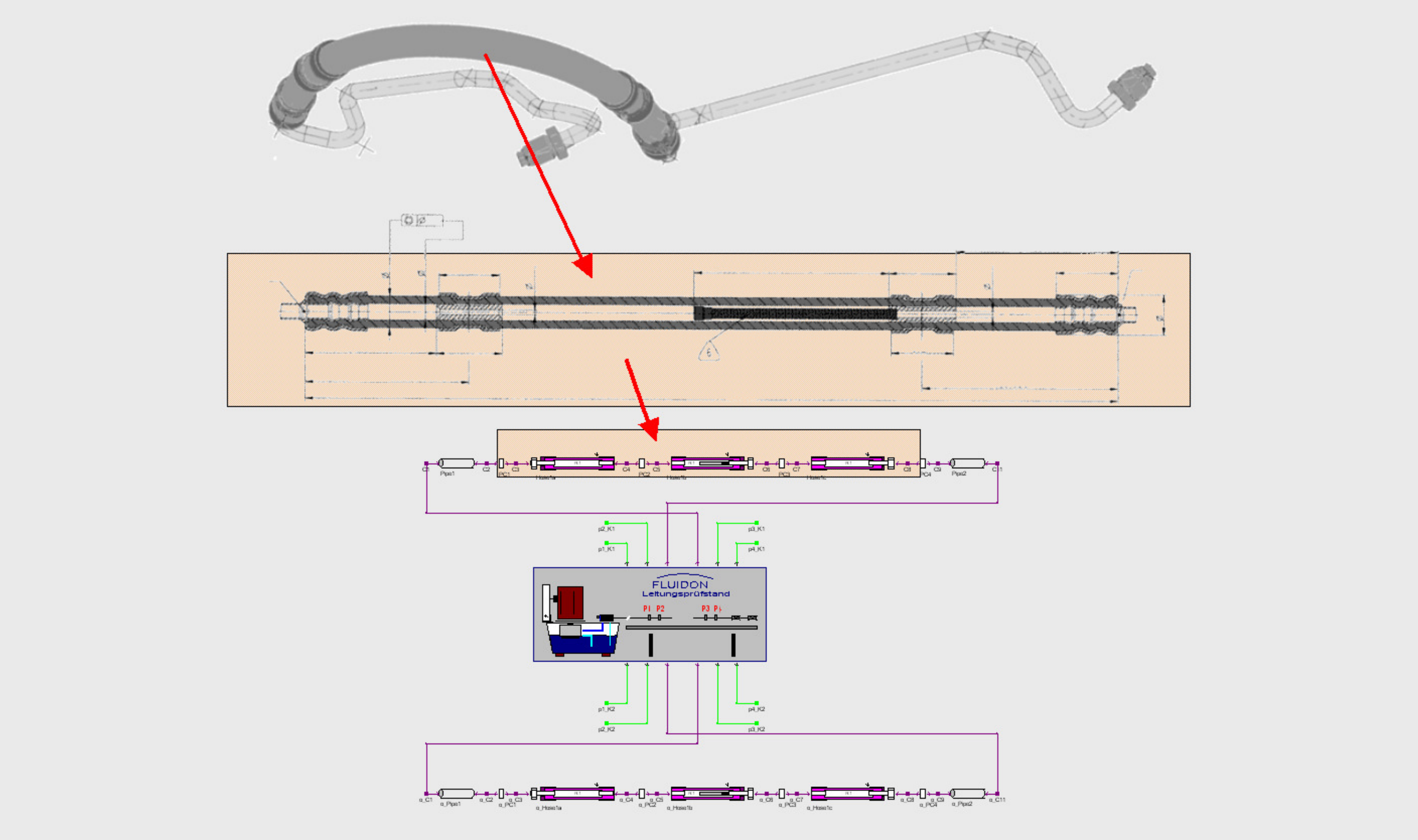


Figure 23

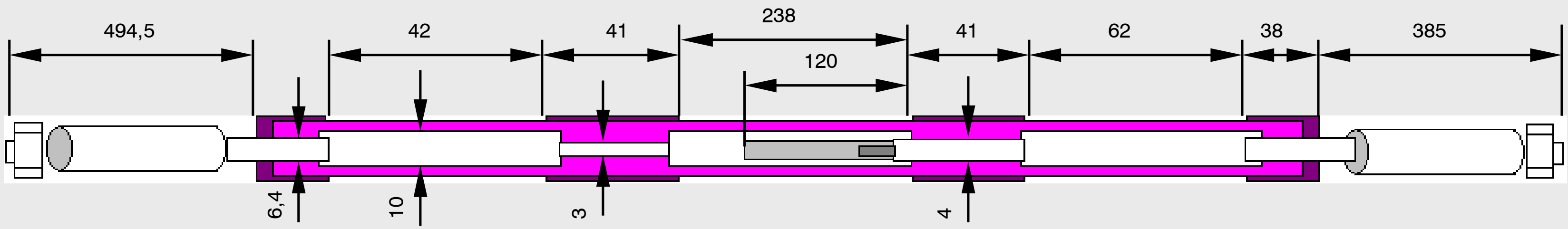
Simulation model of a one-chamber line with steel tuner

Simulationsmodell einer Ein-Kammer-Leitung Stahltuner



Example for a robustness analysis of the steel tuner line

Beispiel für eine Robustheitsanalyse der Stahltunerleitung

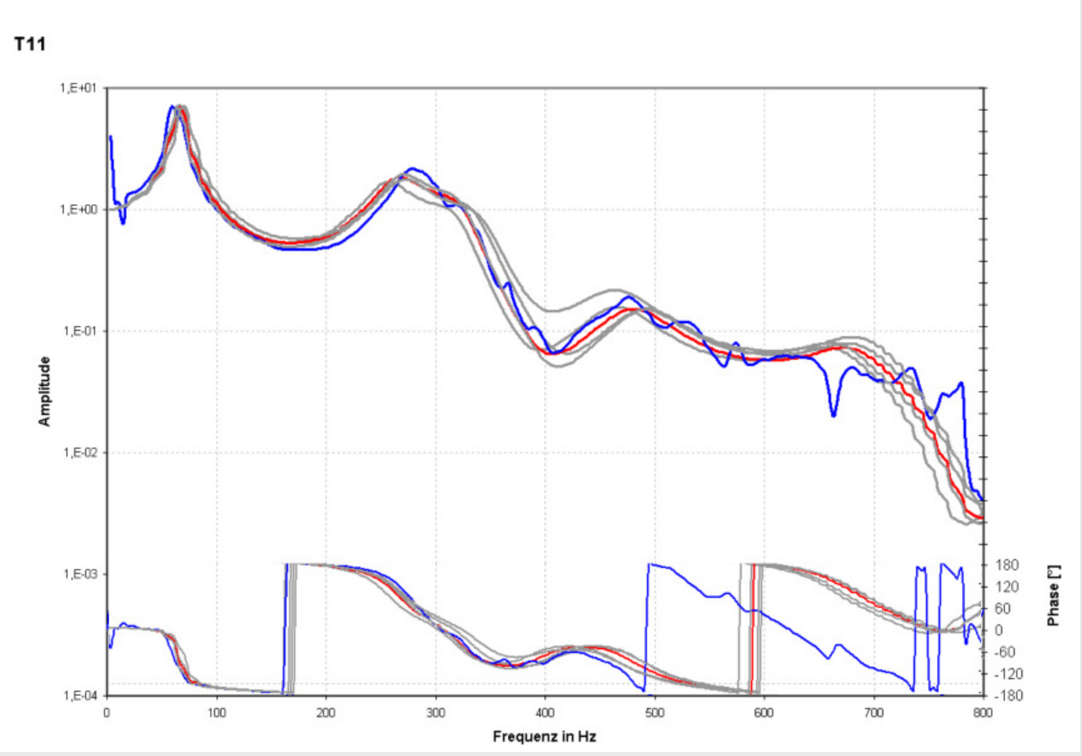


T11 represents the transfer function of pressure input (pump side) to pressure output (steering gear side)

Blue: Measured transfer function

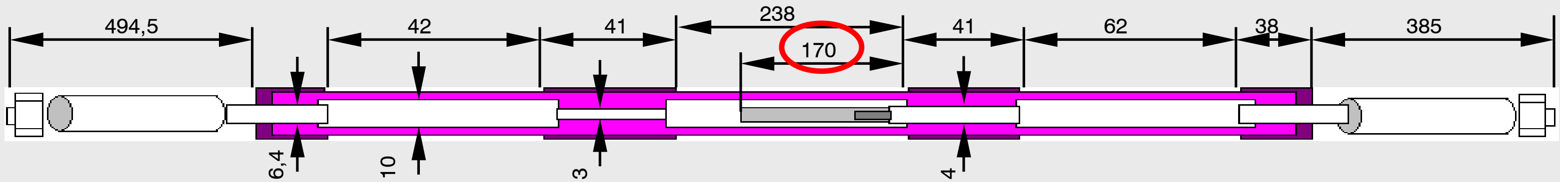
Red: Simulation with exact geometrical values

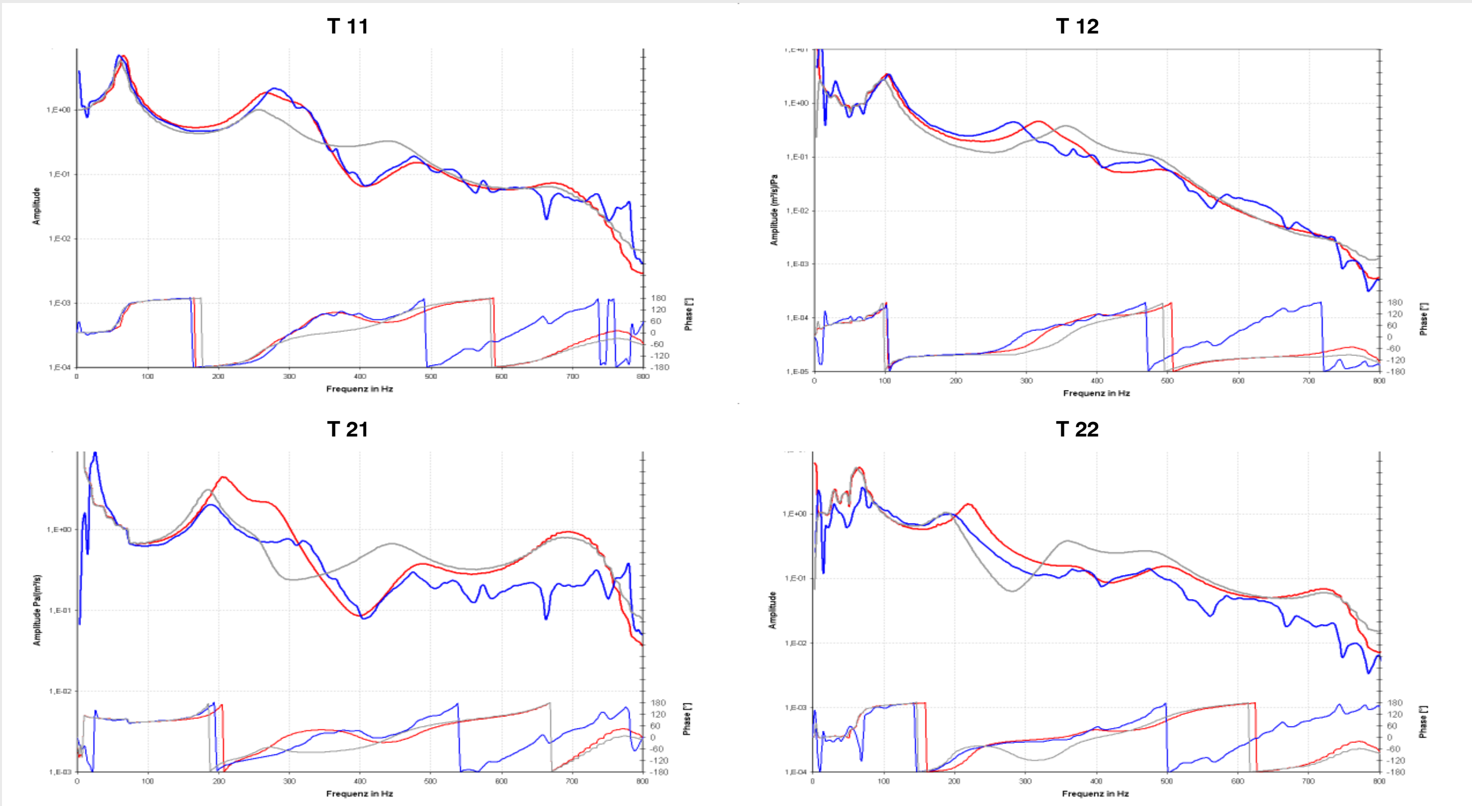
Grey: Simulation with tolerated geometrical values



Sensitivity analysis of the tuner length

Sensitivitätsanalyse der Tunerlänge

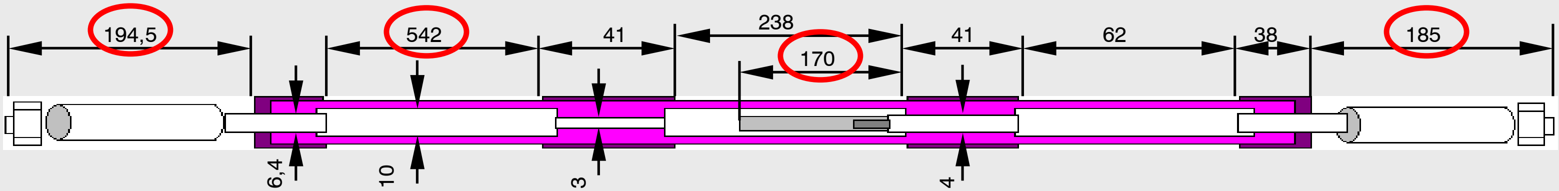


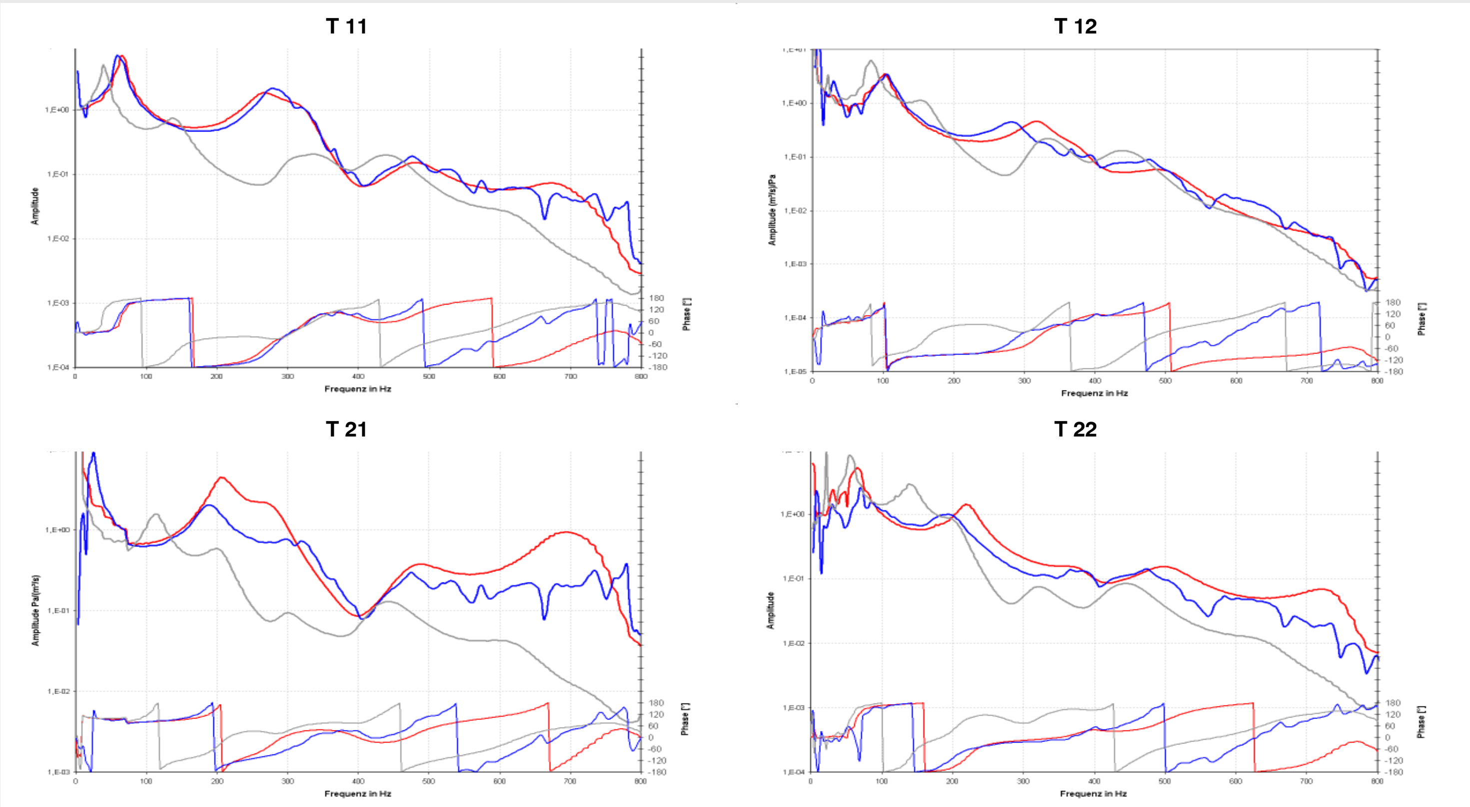


l_{Tuner} = 170 mm (+50 mm)

Sensitivity analysis of hose and pipe length

Sensitivitätsanalyse der Schlauch- und Rohrlänge

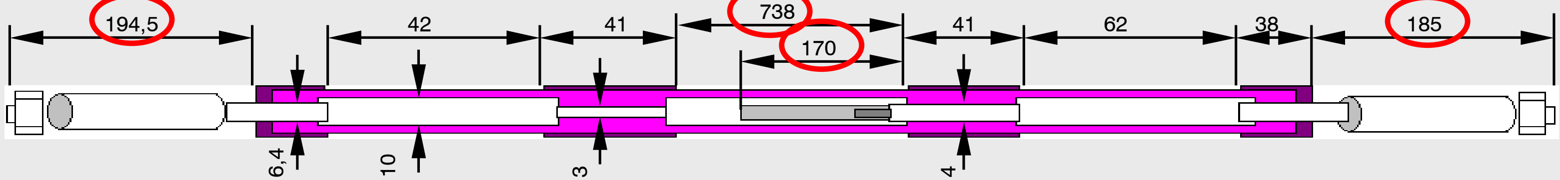


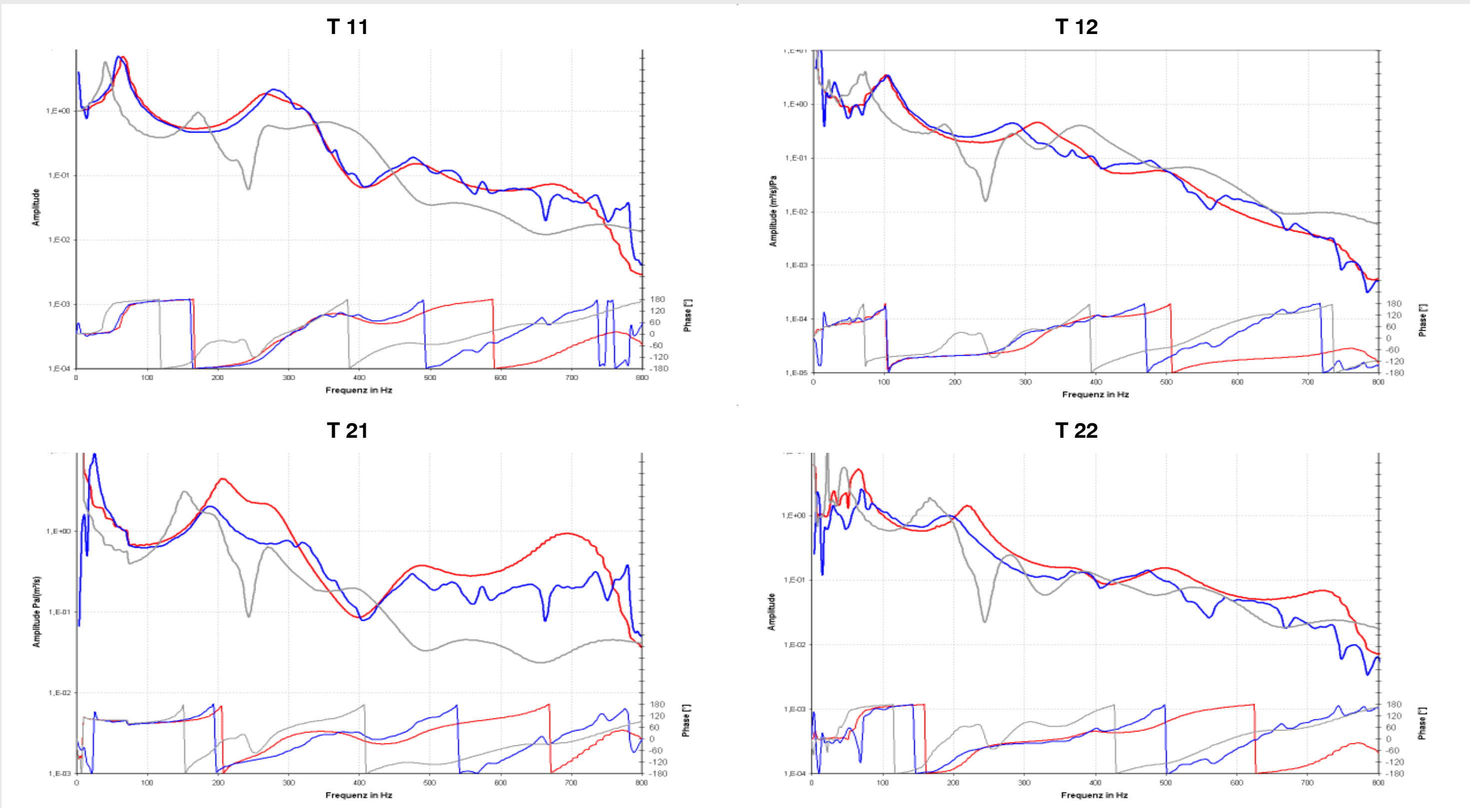


l_{Tuner} = 170 mm, l_{Hose}.1a = + 500 mm, Σ $l_{Pipe\ 1,\ 2}$ = – 500mm

Sensitivity analysis of hose and pipe length

Sensitivitätsanalyse der Schlauch- und Rohrlänge

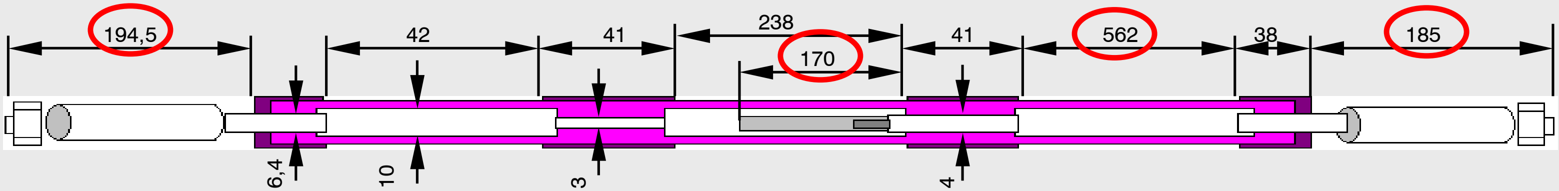


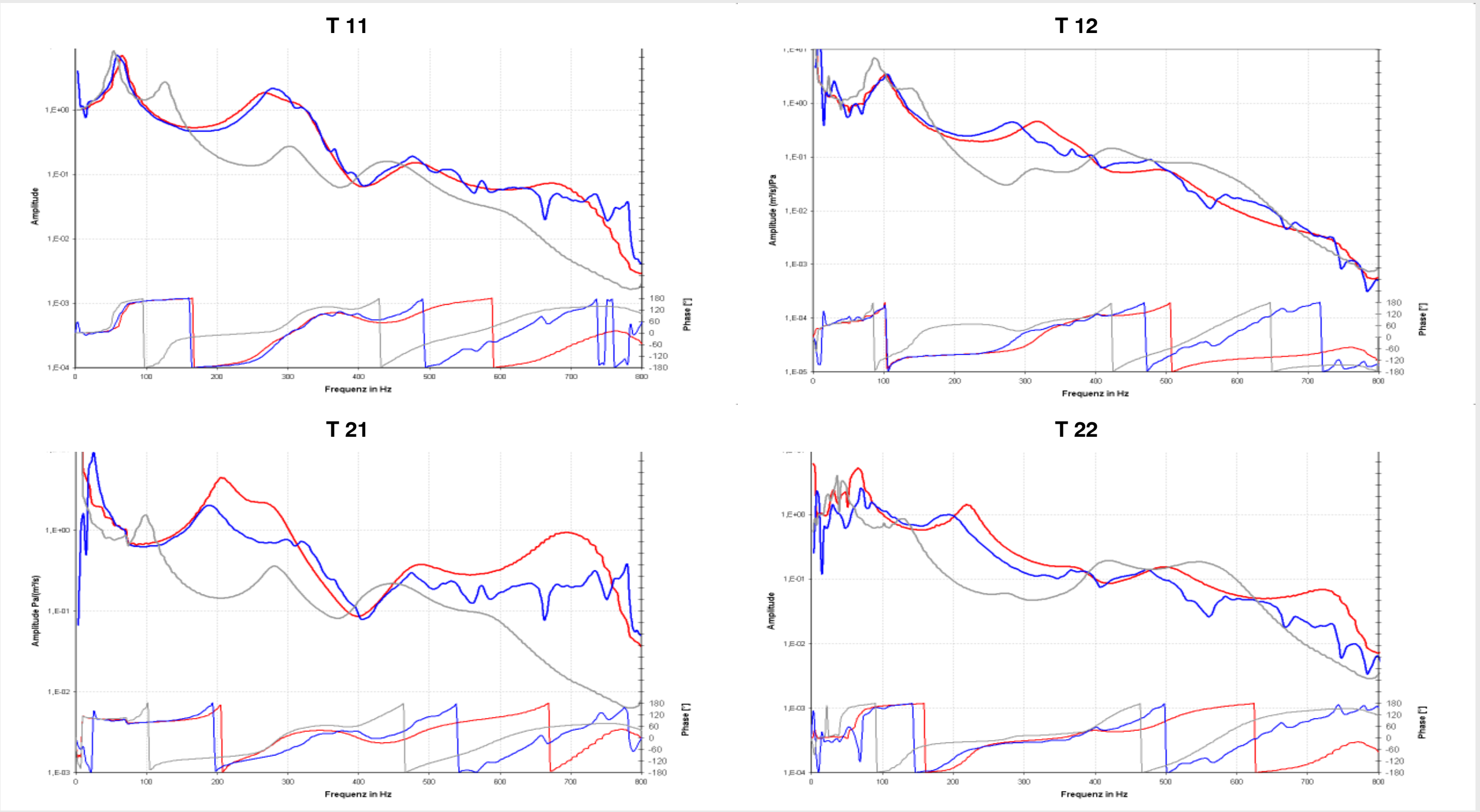


$l_{Tuner} = 170$ mm, $l_{Hose}.1b = +500$ mm, $\Sigma\, l_{Pipe\ 1,2} = -500$mm

Sensitivity analysis of hose and pipe length

Sensitivitätsanalyse der Schlauch- und Rohrlänge

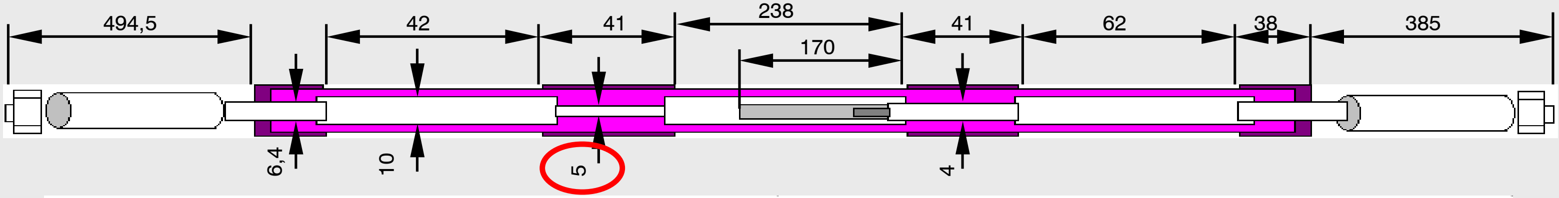


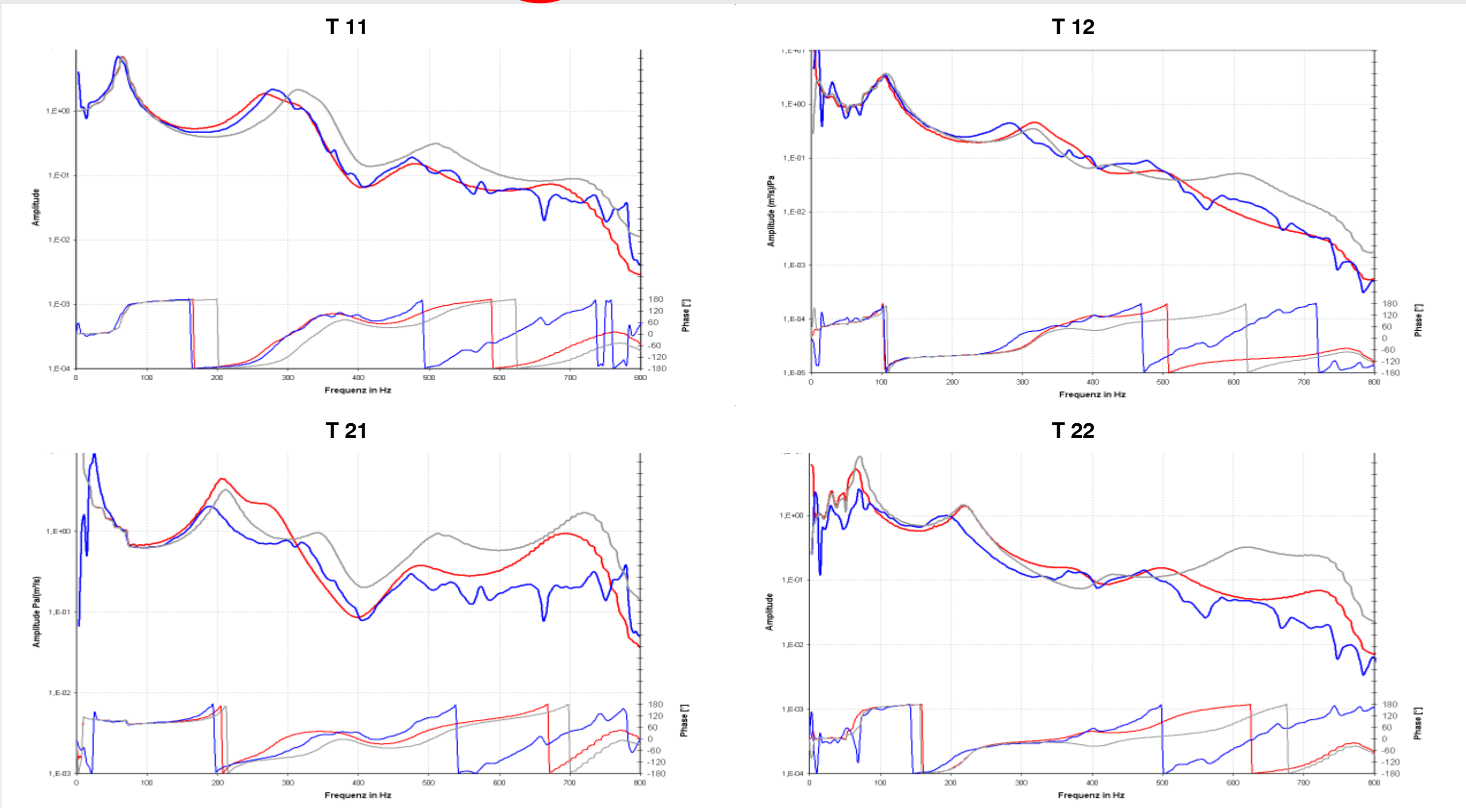


l_{Tuner} = 170 mm, l_{Hose}.1c = + 500 mm, $\Sigma\, l_{Pipe\ 1,\ 2}$ = – 500mm

Sensitivity analysis of throttle diameter

Sensitivitätsanalyse des Drosseldurchmessers

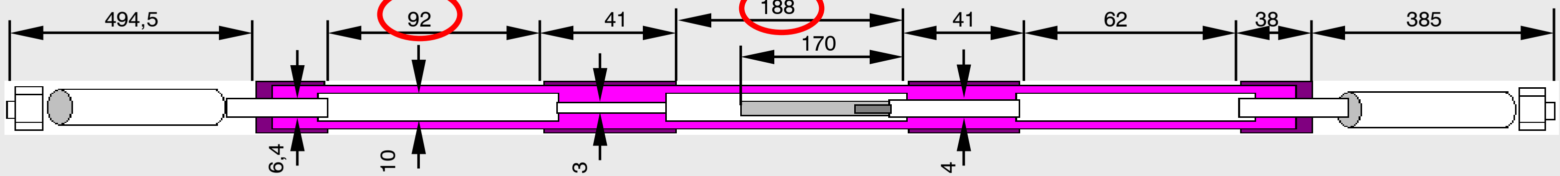


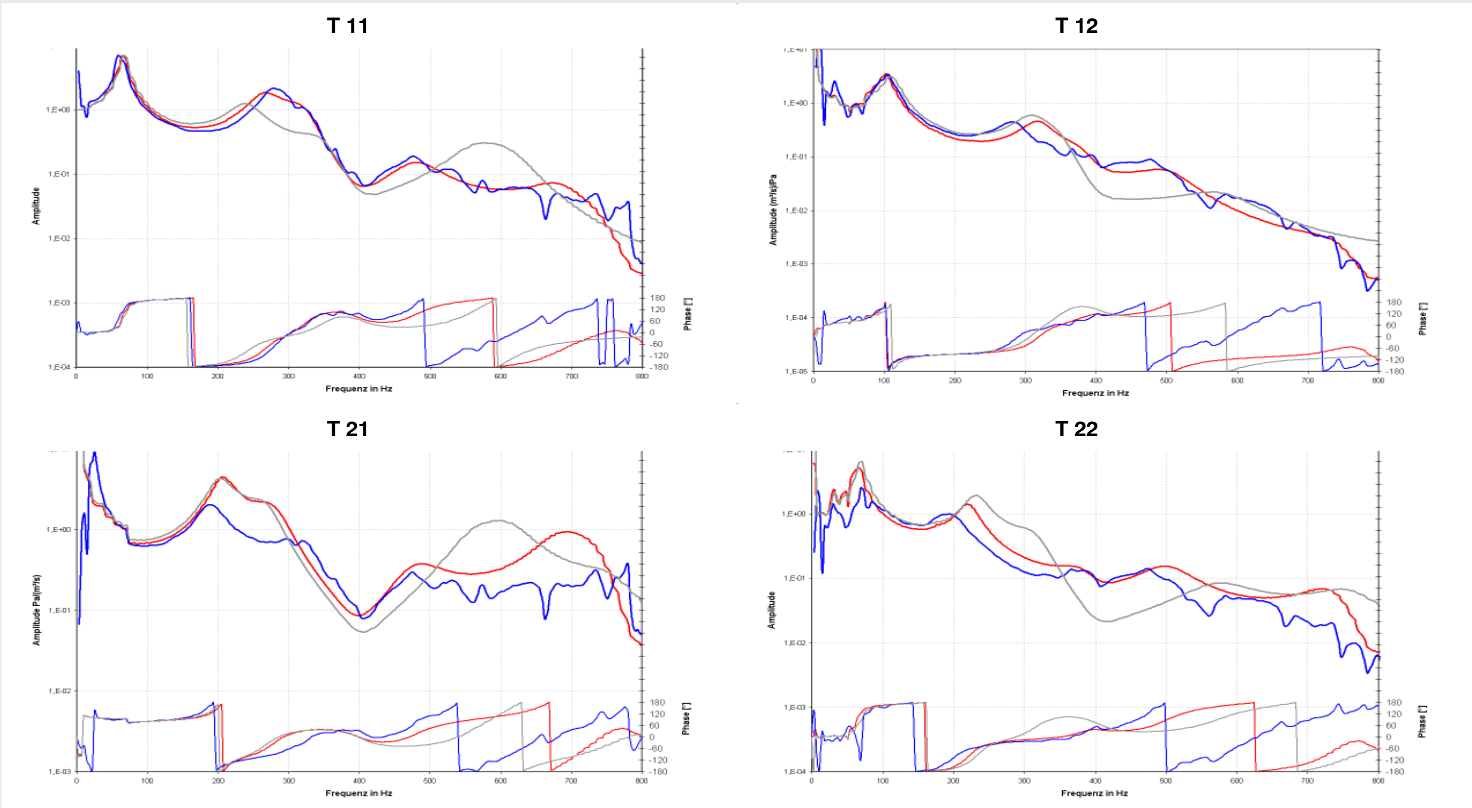


l_{Tuner} = 170 mm, $d_{Throttle}$ = 5 mm

Sensitivity analysis of throttle position

Sensitivitätsanalyse des Drosselposition





l_{Tuner} = 170 mm, l_{Hose}.1a = + 50 mm, l_{Hose}.1b = - 50 mm,

Summary

- By means of the new **DSH***plus* automotive hose library it is now possible to start the design of automotive lines using a virtual prototype. Based on a set of basic line elements the optimization of such lines can be automated using computer simulation.

- About variations of the geometry parameters a sensitivity and robustness analysis can very comfortably be carried out for the line design, e.g. by means of Doe techniques. The custom-designed application of automotive hose lines is not only accelerated by this, effort and costs for final tests with hardware prototypes are also reduced considerably.