Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Numerical simulation, validation, and analysis of two-phase slug flow in horizontal pipes

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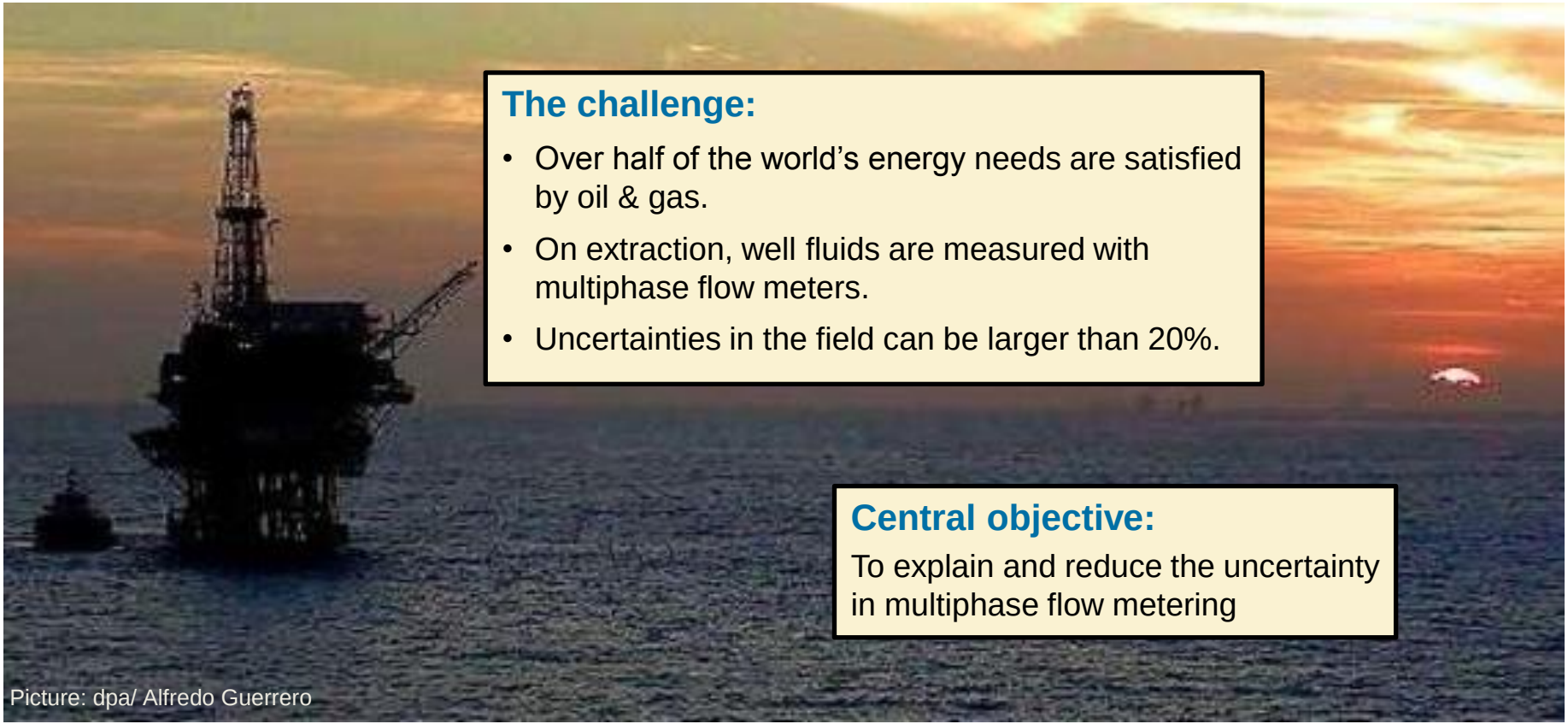
EMPIR project “Multiphase flow reference metrology”



The challenge:

- Over half of the world’s energy needs are satisfied by oil & gas.
- On extraction, well fluids are measured with multiphase flow meters.
- Uncertainties in the field can be larger than 20%.

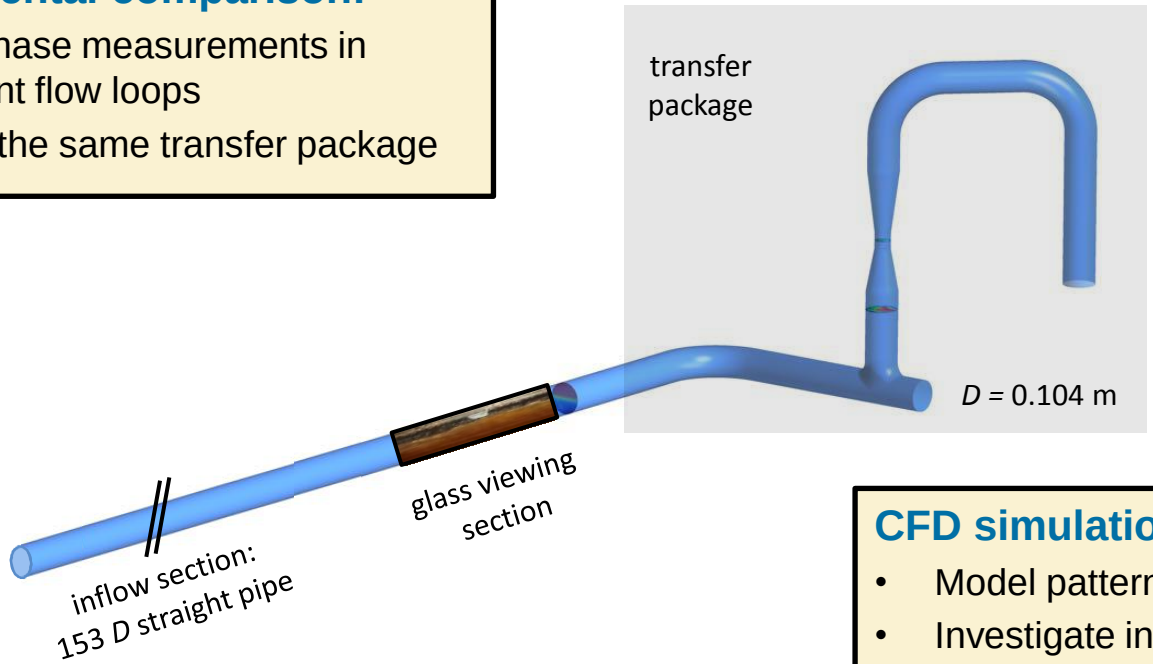
Central objective:

To explain and reduce the uncertainty in multiphase flow metering

Picture: dpa/ Alfredo Guerrero

Experimental comparison:

- Multiphase measurements in different flow loops
- Using the same transfer package



CFD simulations:

- Model pattern formation in inflow section
- Investigate influence of parameters on dp measurement

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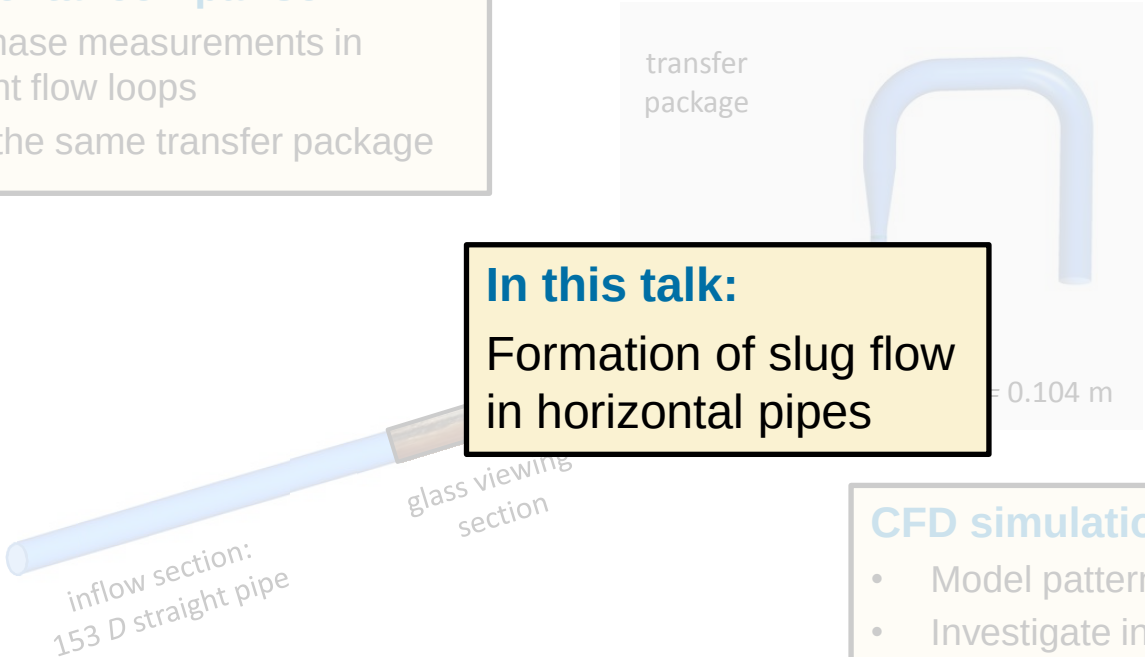

In this talk:

Formation of slug flow in horizontal pipes

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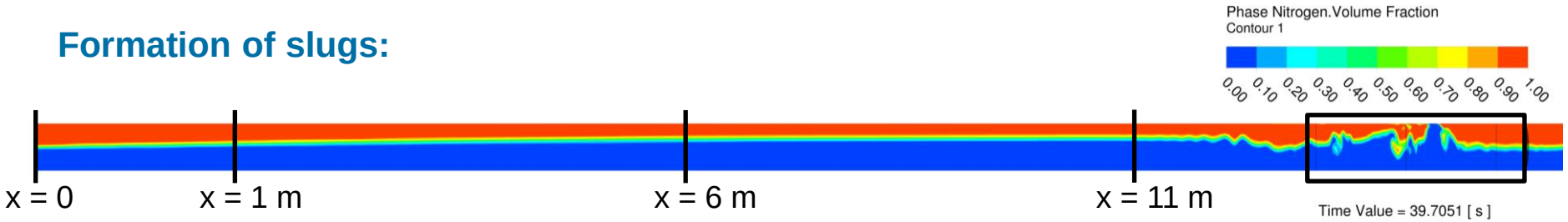
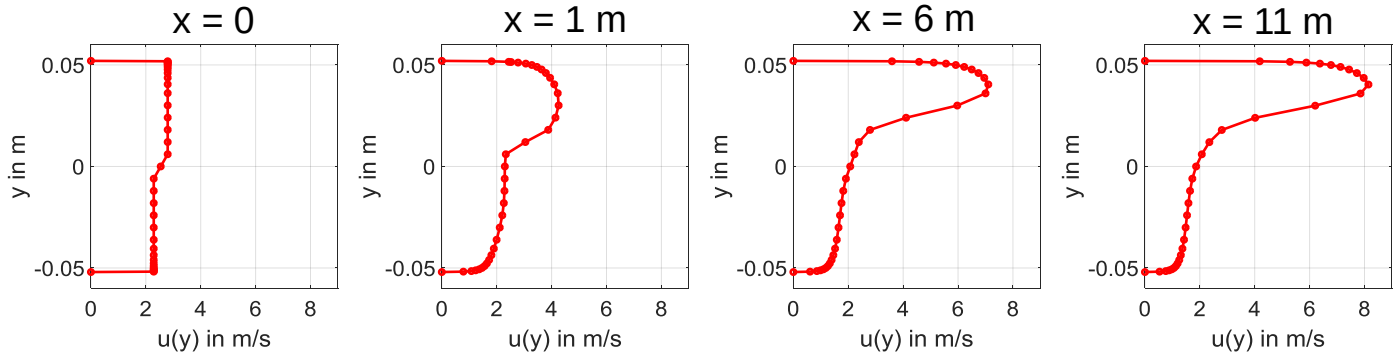
- Investigate influence of parameters on dp measurement

Formation of slug flow in horizontal pipes

Formation of slugs:

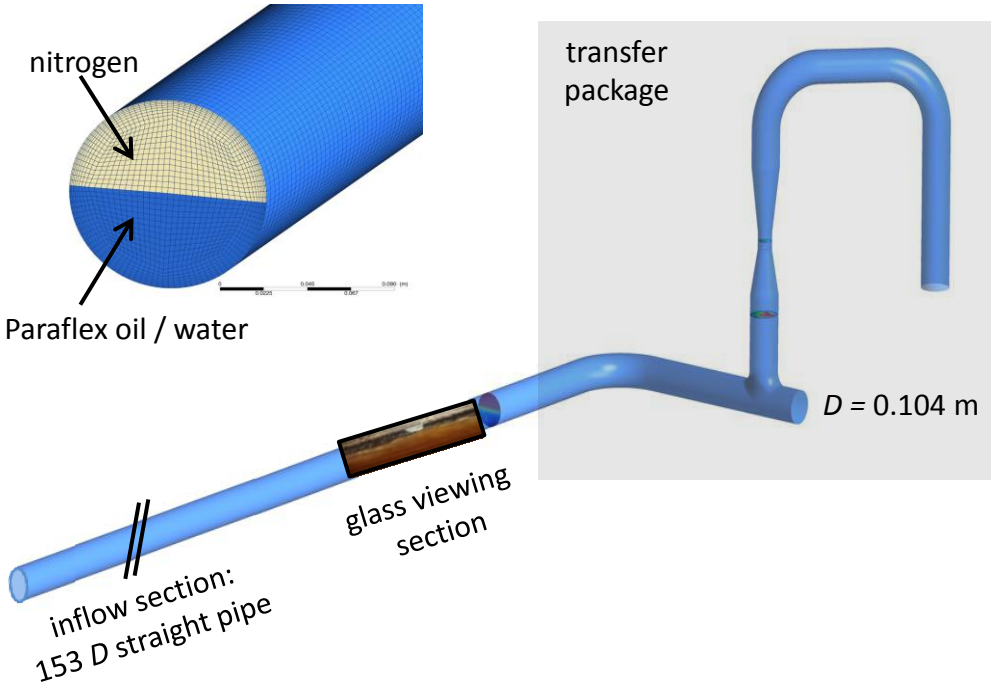


Axial velocity profiles at different x-positions:



Considered test cases

Two-phase flow (oil / water – gas):



Material parameters:

	Nitrogen	Paraflex oil	Water
Density in kg m^{-3}	10.8	815.8	1011
Dyn. visc. in Pa s	$1.75 \cdot 10^{-5}$	$7.84 \cdot 10^{-3}$	$8.82 \cdot 10^{-4}$

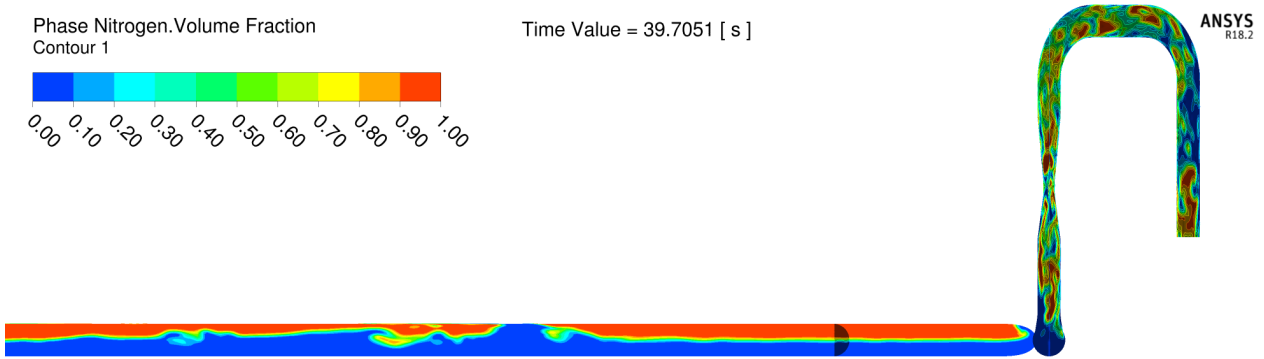
Superficial velocities:

Superficial vel. in m/s	Nitrogen	Paraflex oil	Water
Test case 01	7.063	0.294	-
Test case 77	7.063	-	0.294
Test case 03	1.399	1.144	-
Test case 79	1.399	-	1.144
Test case 05	0.545	1.635	-
Test case 81	0.545	-	1.635

Simulation results for selected test cases

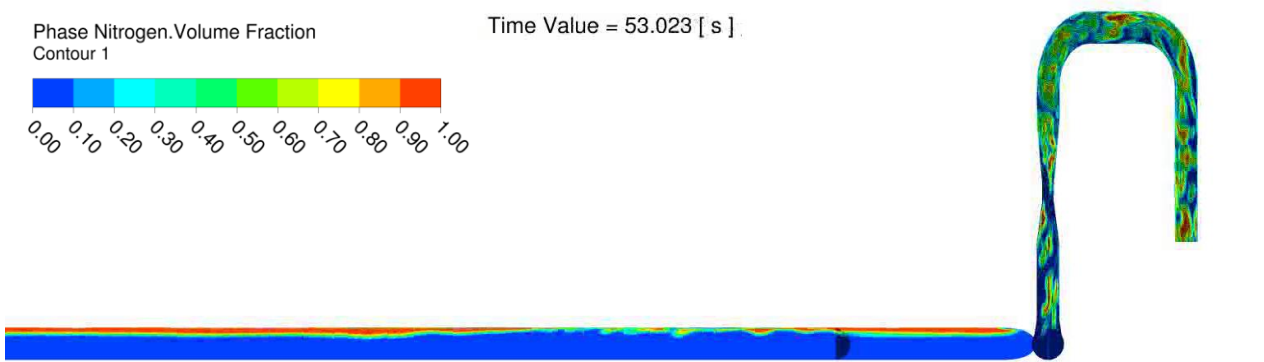
TP 79 (water – gas):

v_{sg} = 1.399 m/s
v_{sl} = 1.144 m/s



TP 05 (oil – gas):

v_{sg} = 0.545 m/s
v_{sl} = 1.635 m/s

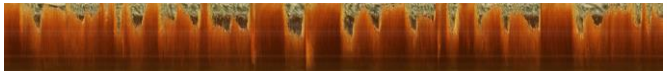


Extraction of liquid level from video observations

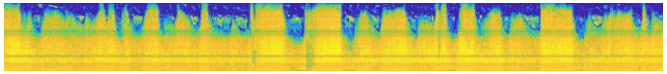
Oil – gas:

ROI

ROI over time

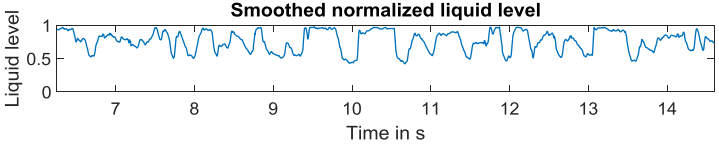


Blue component of ROI over time

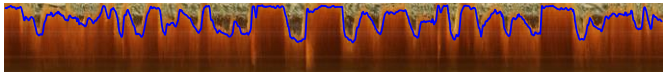


Result of morphological filter process

Smoothed normalized liquid level



Comparison of liquid level and video

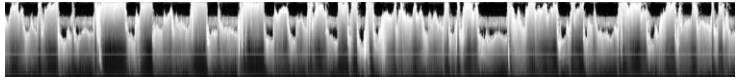


Water – gas:

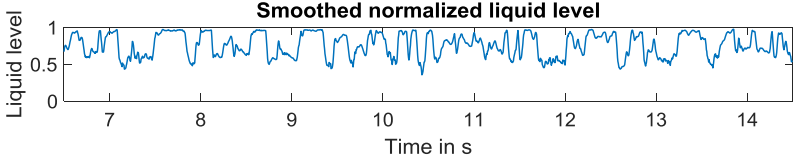
ROI

Gray scale of ROI over time

Result of Gaussian filter and contrast enhancement



Smoothed normalized liquid level



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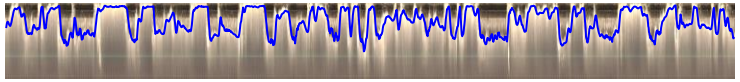
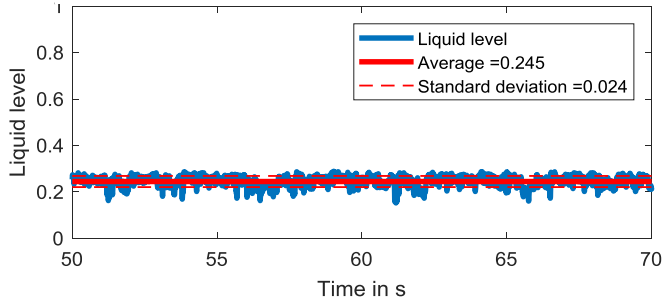


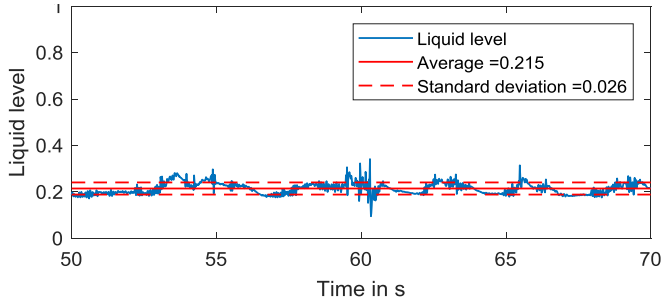
Comparison between simulation and experiment

Test point 01:

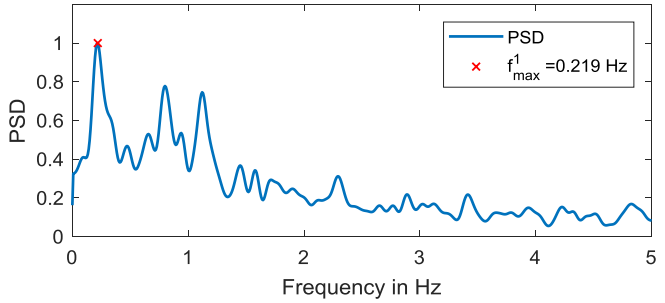
Experiment: av. liquid level: 0.245



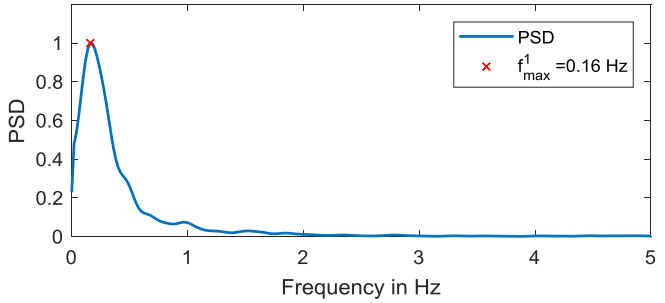
Simulation: av. liquid level: 0.215



Experiment: max. freq.: 0.219 Hz



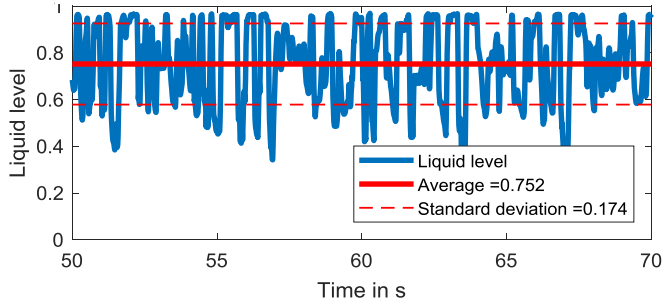
Simulation: max. freq.: 0.16 Hz



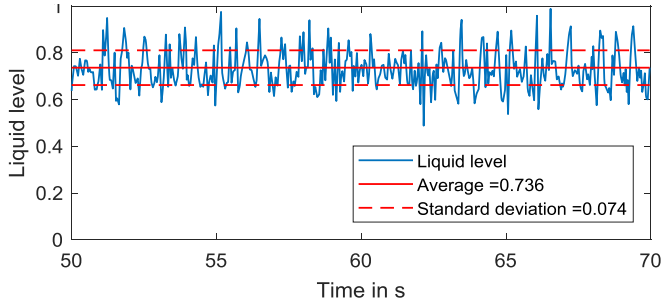
Comparison between simulation and experiment

Test point 81:

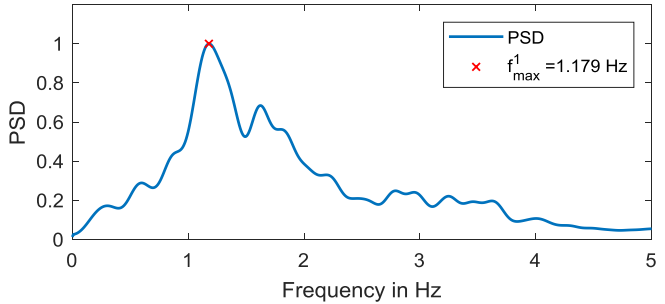
Experiment: av. liquid level: 0.752



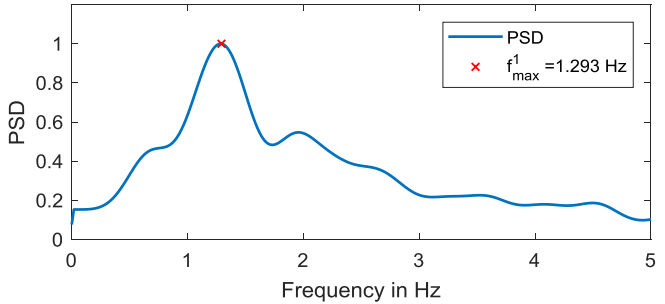
Simulation: av. liquid level: 0.736



Experiment: max. freq.: 1.179 Hz

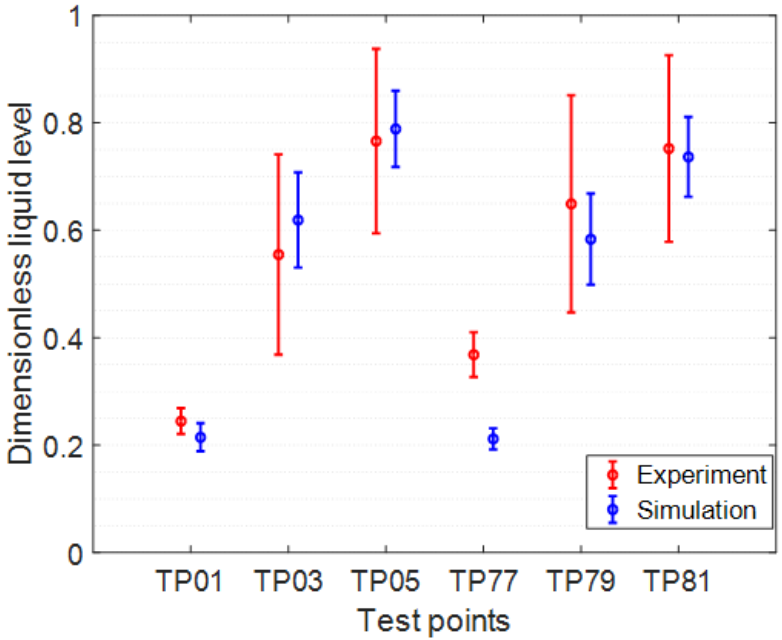


Simulation: max. freq.: 1.293 Hz



Results for the different test cases

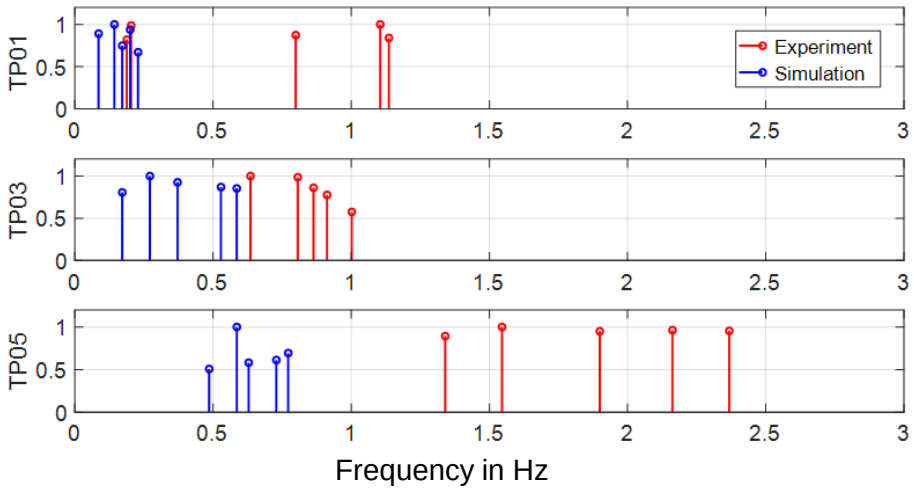
Liquid level (mean ± standard deviation):

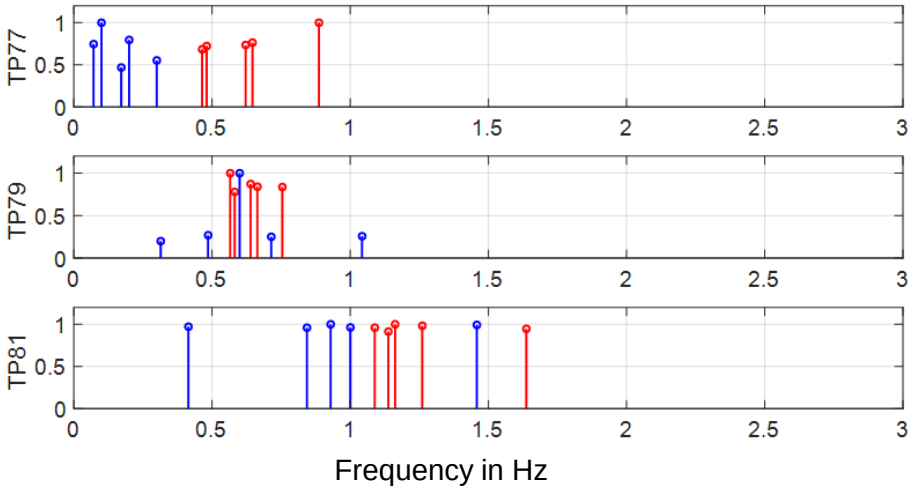


- Increase of liquid level with increasing liquid superficial velocity
- Good agreement between experiment and simulation for mean liquid level (except for TP 77)
- Standard deviation in simulation smaller than in experiment

Results for the different test cases

Five dominant frequencies of FFT:





Increase of dominant frequencies with increasing liquid superficial velocity

Summary and Outlook

Summary:

- Simulation of different slug flow test cases
- Validation of CFD models by comparison with experimental data

  → good agreement for average liquid level (except for TP 77)
- Frequency analysis of experimental and simulation data

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⟶ Talk by Marc Olbrich on Friday

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Thank you very much for your attention.

EMPIR

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