Fluid-Struktur-Oszillation zur Drainageoptimierung bei der Druckluftfiltration

IGF-Projekt-Nr. 22456 N

Sitzung des PA
November 2023

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BERGISCHE UNIVERSITÄT WUPPERTAL

Agenda

Repetition

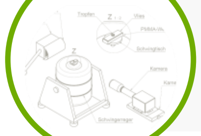
Experimental setup and procedure

Evaluation

Results

Summary and outlook

Repetition



Experimental setup and procedure

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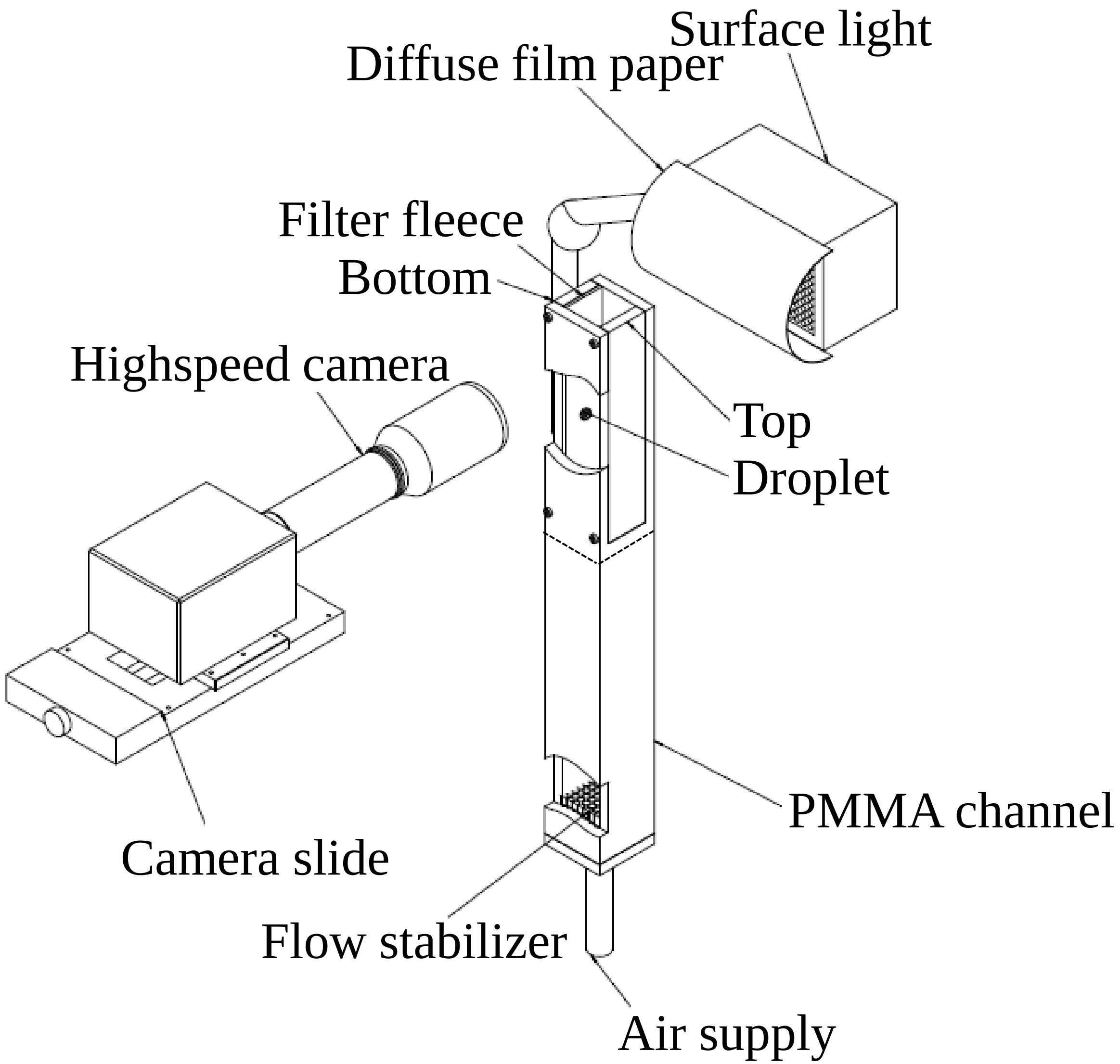
Motivation

- During operation, oil settles in the filter, increasing pressure loss and operating costs
- **Goal:** Reduction of pressure loss and operating costs of the compressor through faster droplet drainage
- The oil droplets grow over time and generate a pressure loss
- When they reach a critical size, they break off and accumulate at the bottom of the tank
- Critical velocity (simplified): the velocity at which the droplet starts to move in the direction of flow
- Droplets that are excited with their characteristic eigenfrequency require a lower critical velocity
- **Idea:** Accelerate the drainage by exciting it with the eigenfrequency so that droplets run off earlier and reduce the pressure loss

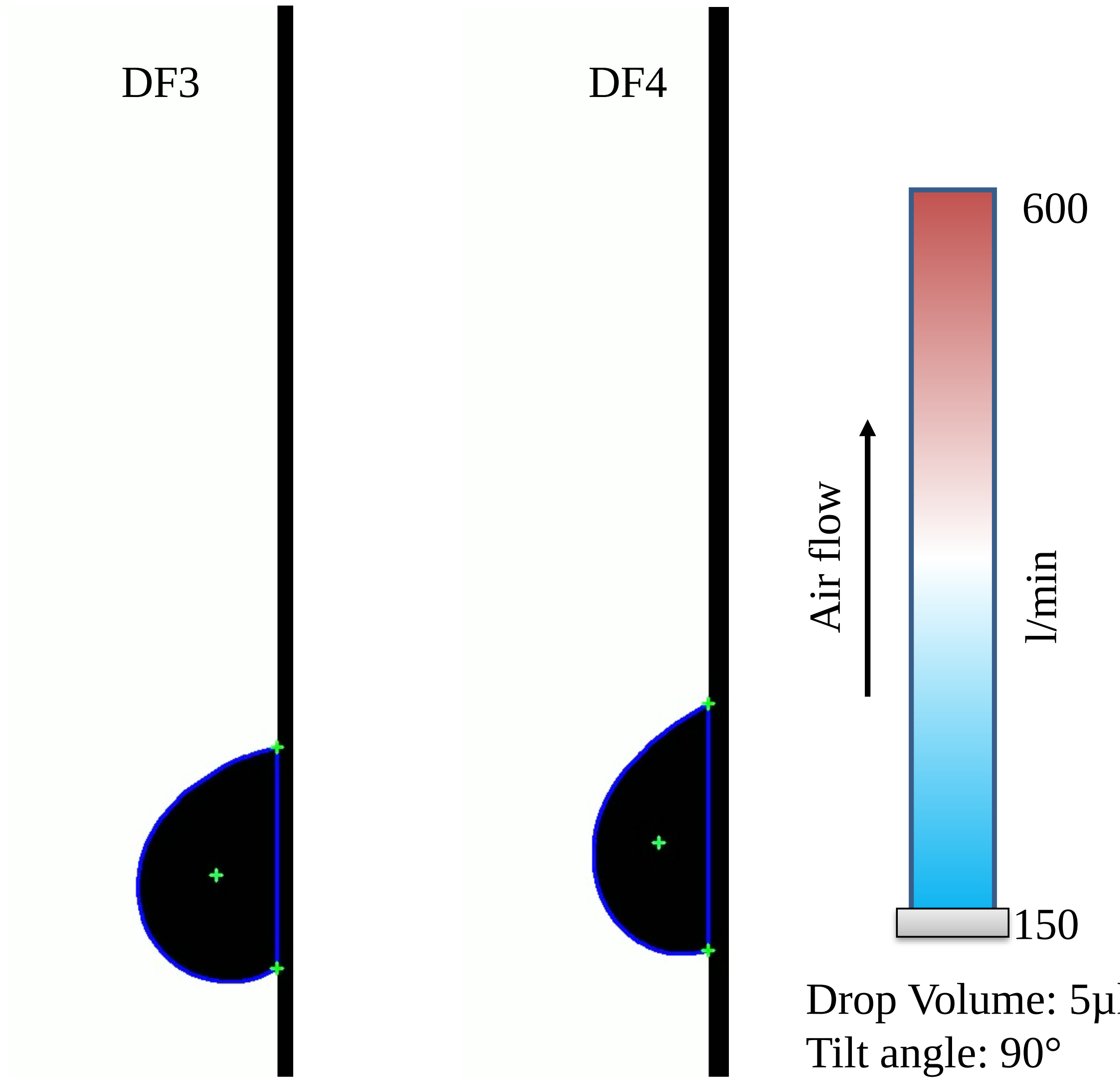
Repetition: Experimental setup Incident flow

- Incoming flow of the droplet
- Acquisition of the contour with a high-speed camera
- Any inclination possible



Vertical inflow tests: flow process

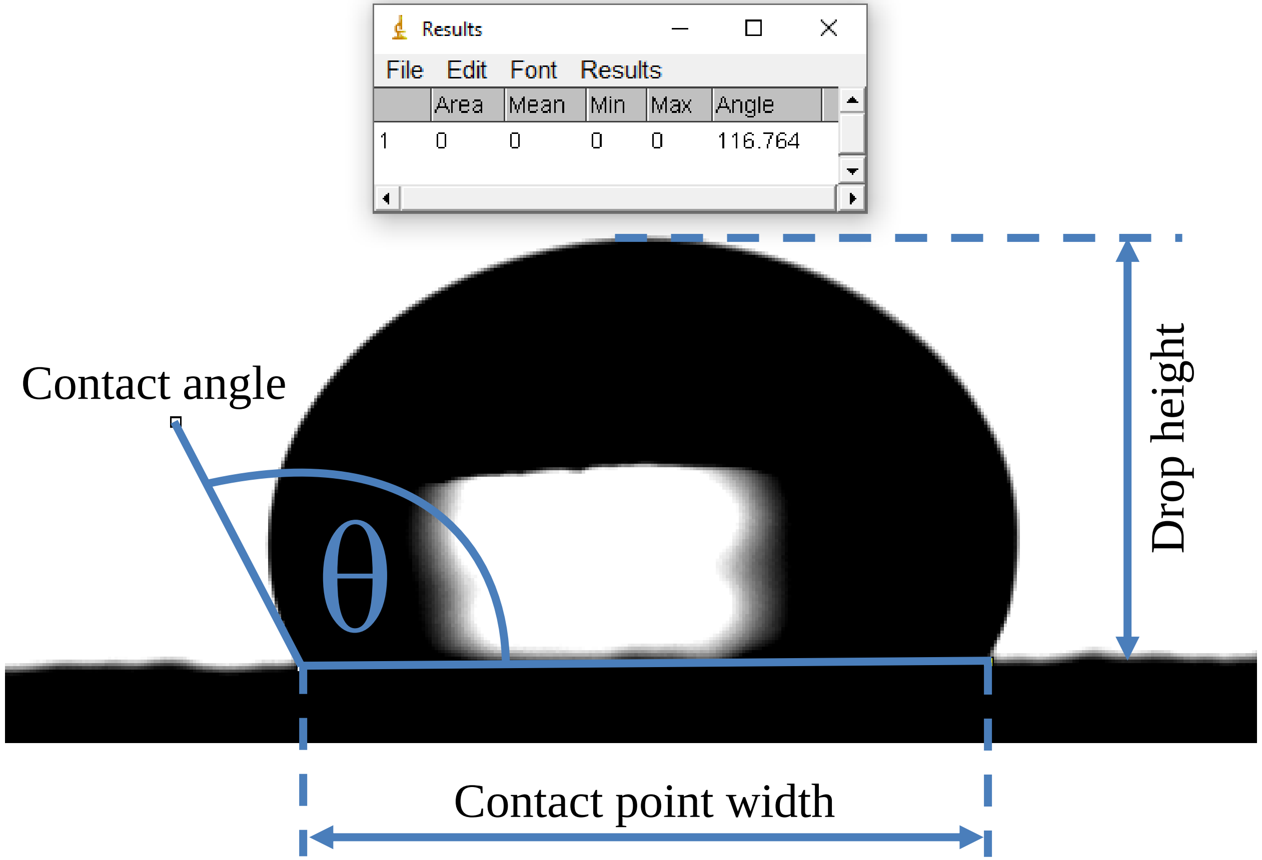
- Linear increase of the volume flow
- Start at droplet oscillation (150 l/min)
- Increase up to 600 l/min (35s)
- Frame rate: 120 Fps



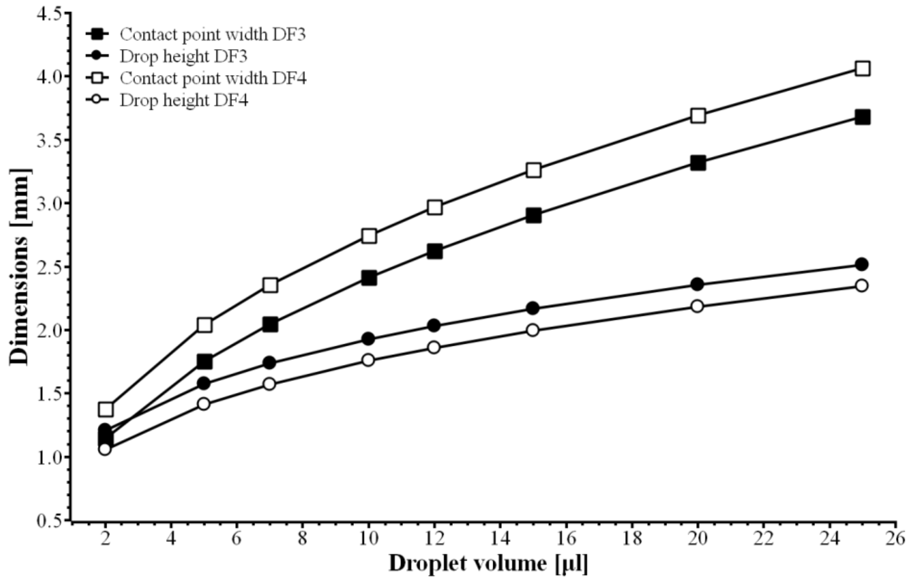
Drop Volume: 5µl
Tilt angle: 90°

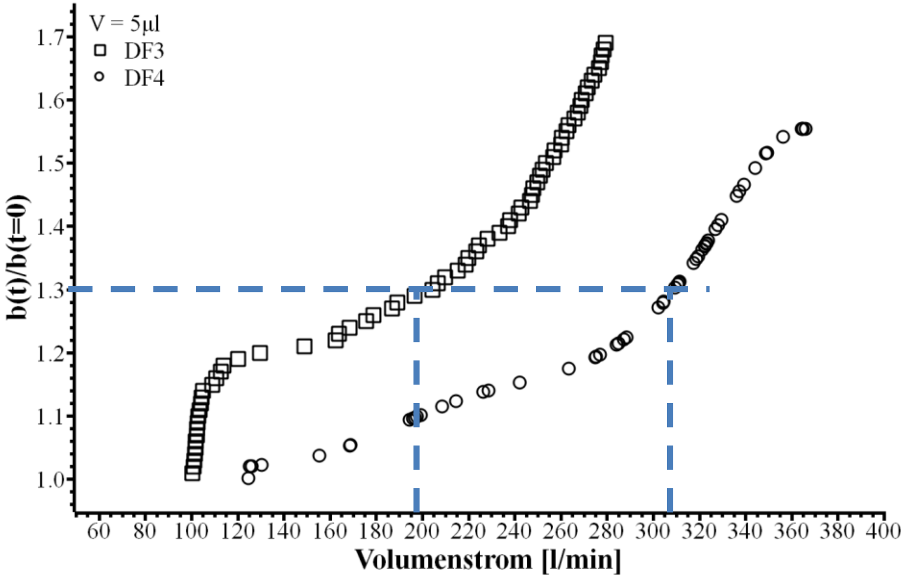
Repetition: Measurement of drop geometry

- Manual acquisition of the contact angles
- Gravitational influence for large droplets
- Bond-number: $Bo = \frac{\rho g R^2}{\sigma}$
  - $Bo \ll 1$: Gravity does not matter
  - $Bo \geq 1$: Gravity has influence
- Drop height & contact point width
- Distance of contact points
- Depends on:
  - Material properties
  - Surface
  - Droplet volume



Repetition: Results





- Slight decrease in contact angles
- $Bo = 1$ for $V_{Drop} \approx 25\mu l$

Fleece	Contact angle
DF3	$112.89° \pm 1.5°$
DF4	$97.49° \pm 0.6°$

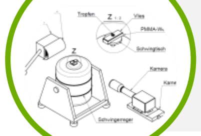
Summary

- Influence of the fleece:

Contact angle	θ_{DF3}	>	θ_{DF4}
Eigenfrequency	EF_{DF3}	<	EF_{DF4}
Drop width	b_{DF3}	<	b_{DF4}
Drop height	t_{DF3}	>	t_{DF4}
Flow limit	$v_{krit,\,DF3}$	>	$v_{krit,\,DF4}$

Agenda

Repetition



Experimental setup and procedure

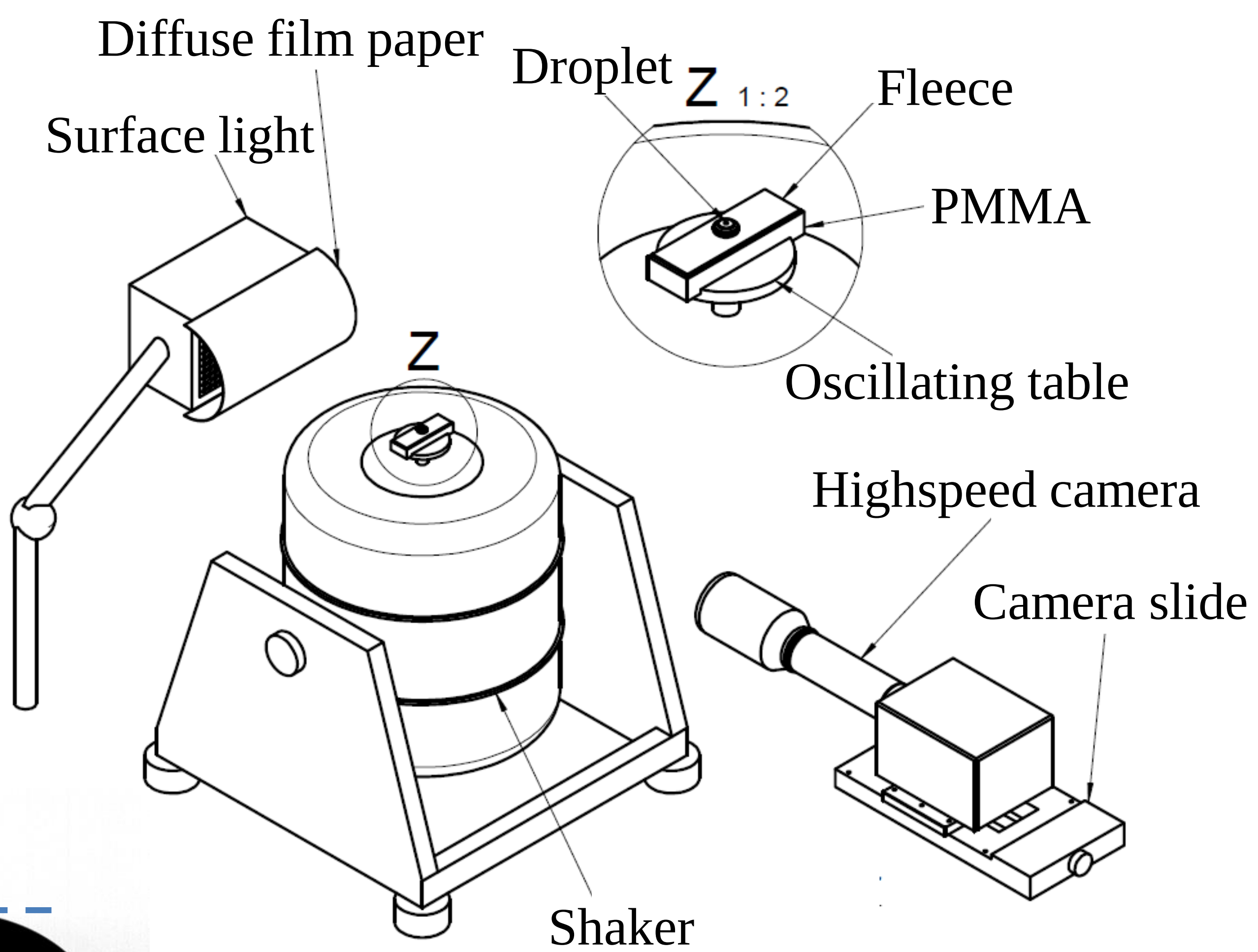
Evaluation

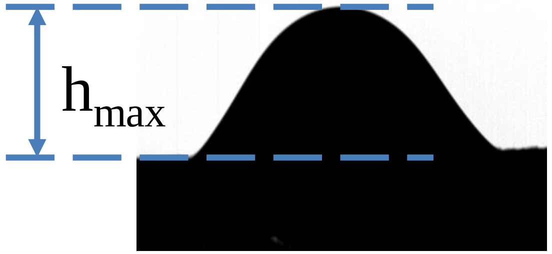
Results

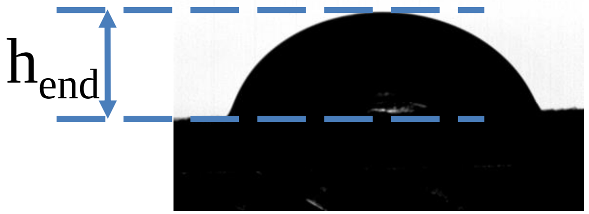
Summary and outlook

Experimental setup and procedure

- Investigation of droplet behavior during oscillation
- Determination of the Eigenfrequency
- Droplet application with a syringe or pump
- Excitation: f=const. and a=const.
- Repeat for frequency range
- Ratio: *h_max/h_end*
- Recording: 4s with 2000 fps







Experiment setup: Pump

- LDS V455 shaker:
  - Frequency range: 5Hz - 7.5kHz
  - Maximum acceleration: 117g
- CETONI Nemesys S [25ml]:
  - 10 bar /145 psi Maximum pressure
  - 318 pl/s - 2.5 ml/s Flow rate

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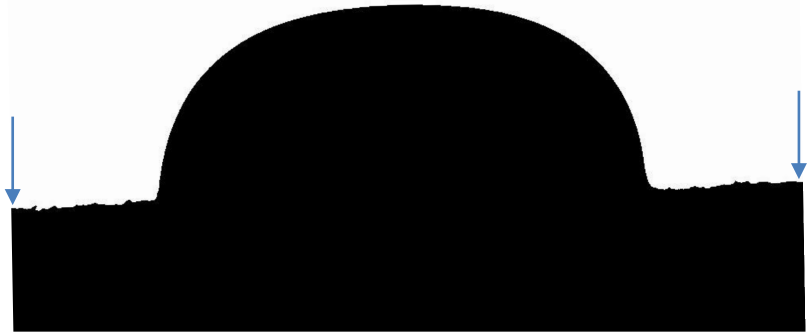
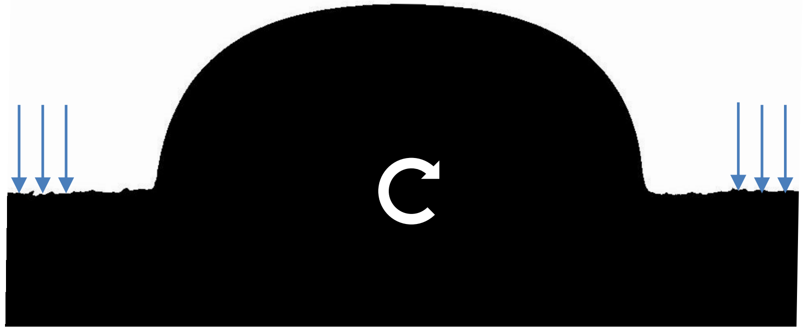
Evaluation: Contour detection

Original image

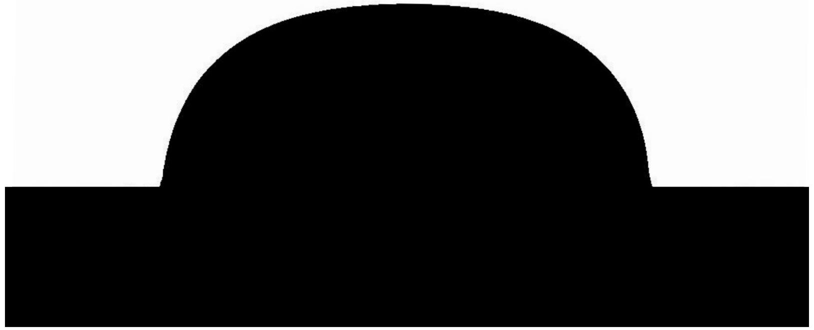
Threshold



Tilt correction via outer points



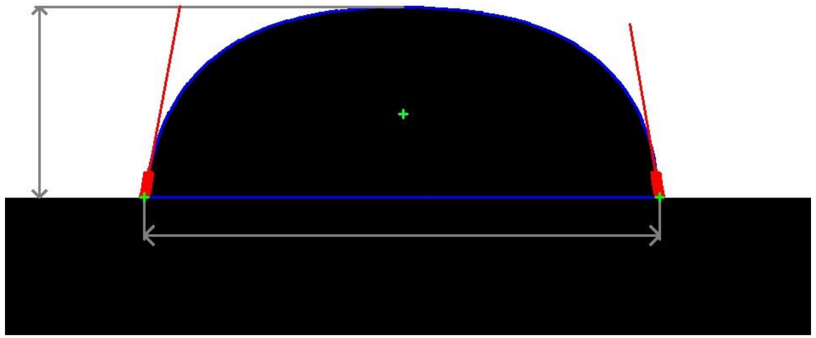
Identification of the bottom layer with 6 points



Contour detection

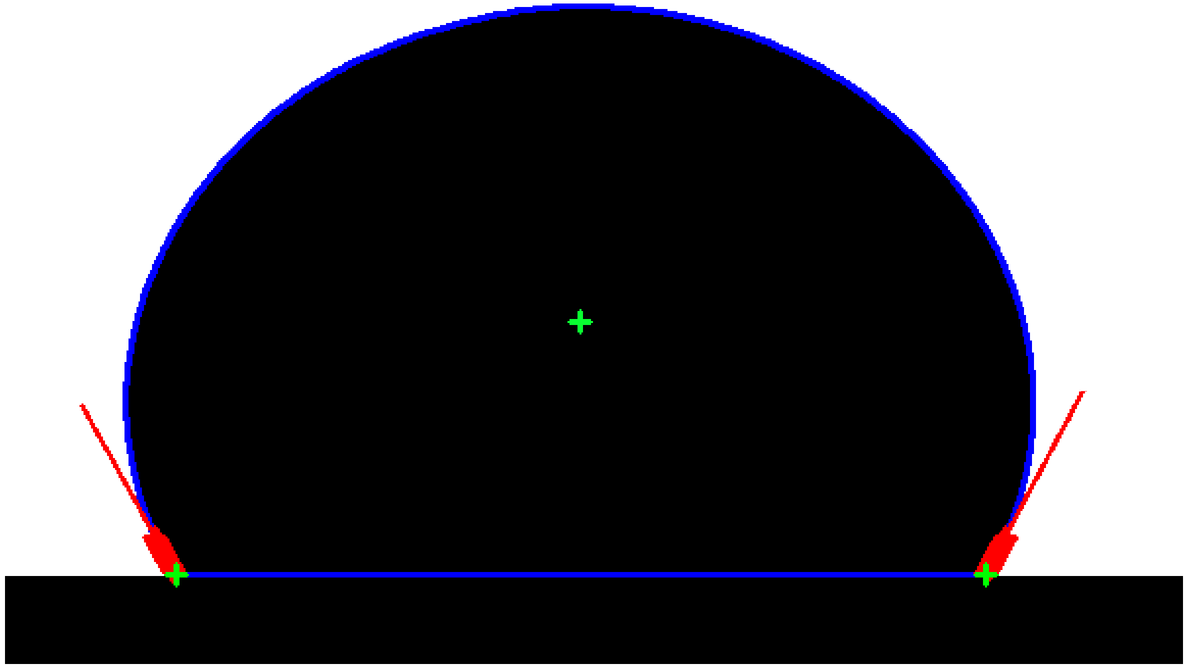
Drop geometry

h = 1.573mm
s = 4.231mm
l = 79.46Grad
r = 80.217Grad
A = 5.387mm2

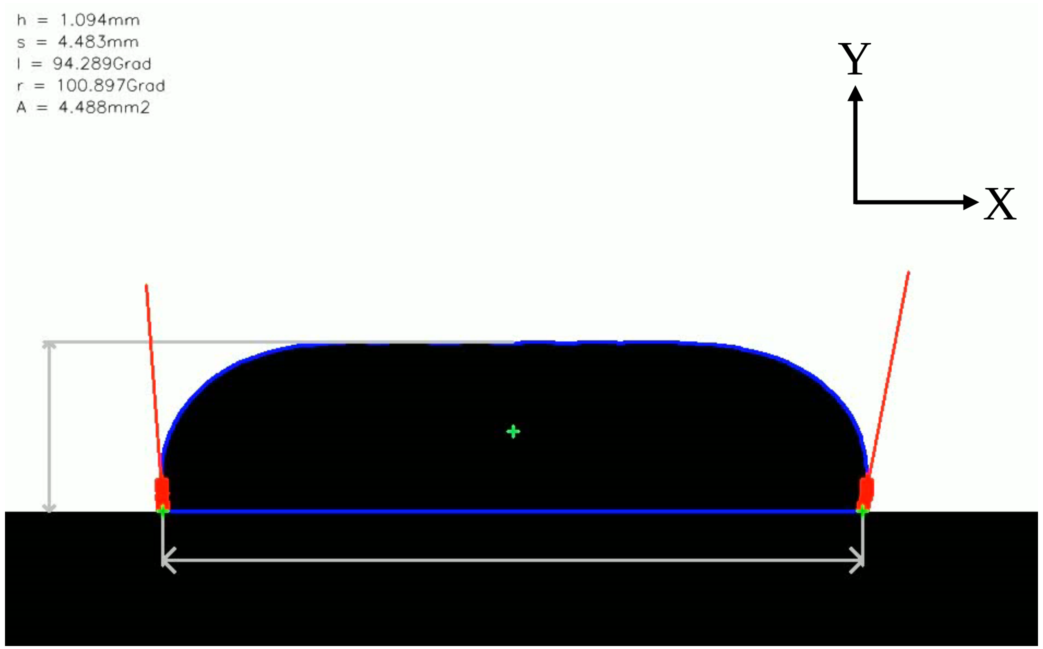


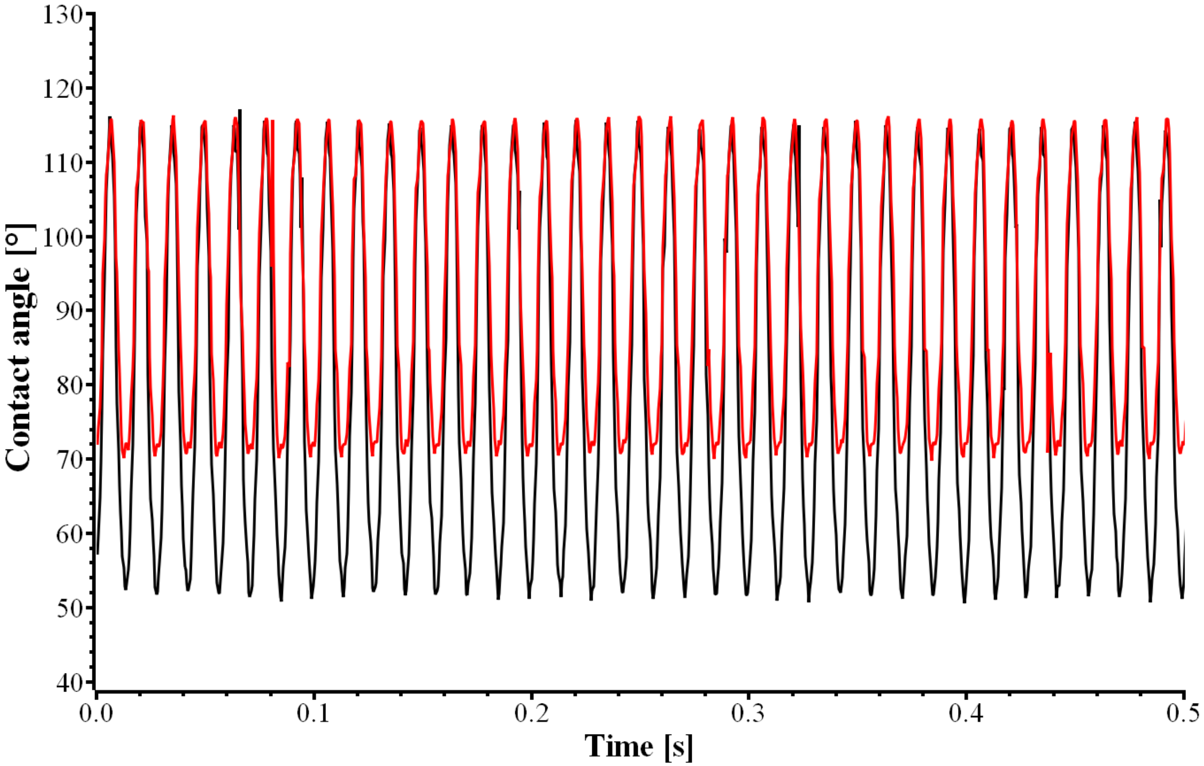
Evaluation: Contour detection

- Conversion to gray image
- Detection of the bottom
  - Tilt correction
- Detection of the contour
- Determination of the:
  - Contact points
  - Center of gravity
  - Drop height
  - contact angle
  - Frequency
  - Drop movement (contact points, center of gravity)



Evaluation: Contour detection Examples





Drop Volume: 7µl (DF4)
Recording rate Camera: 1500 fps
Excitation: 70Hz

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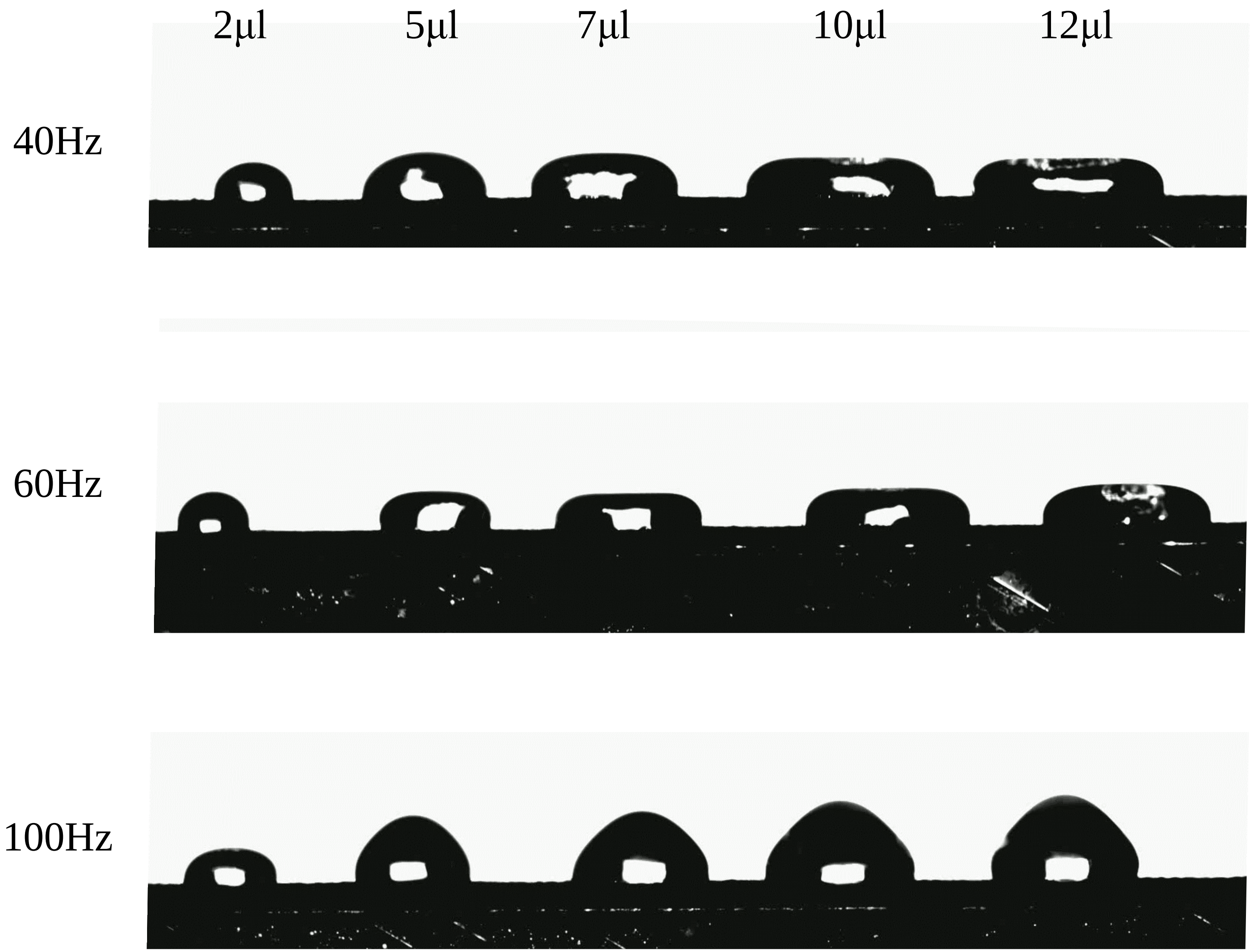
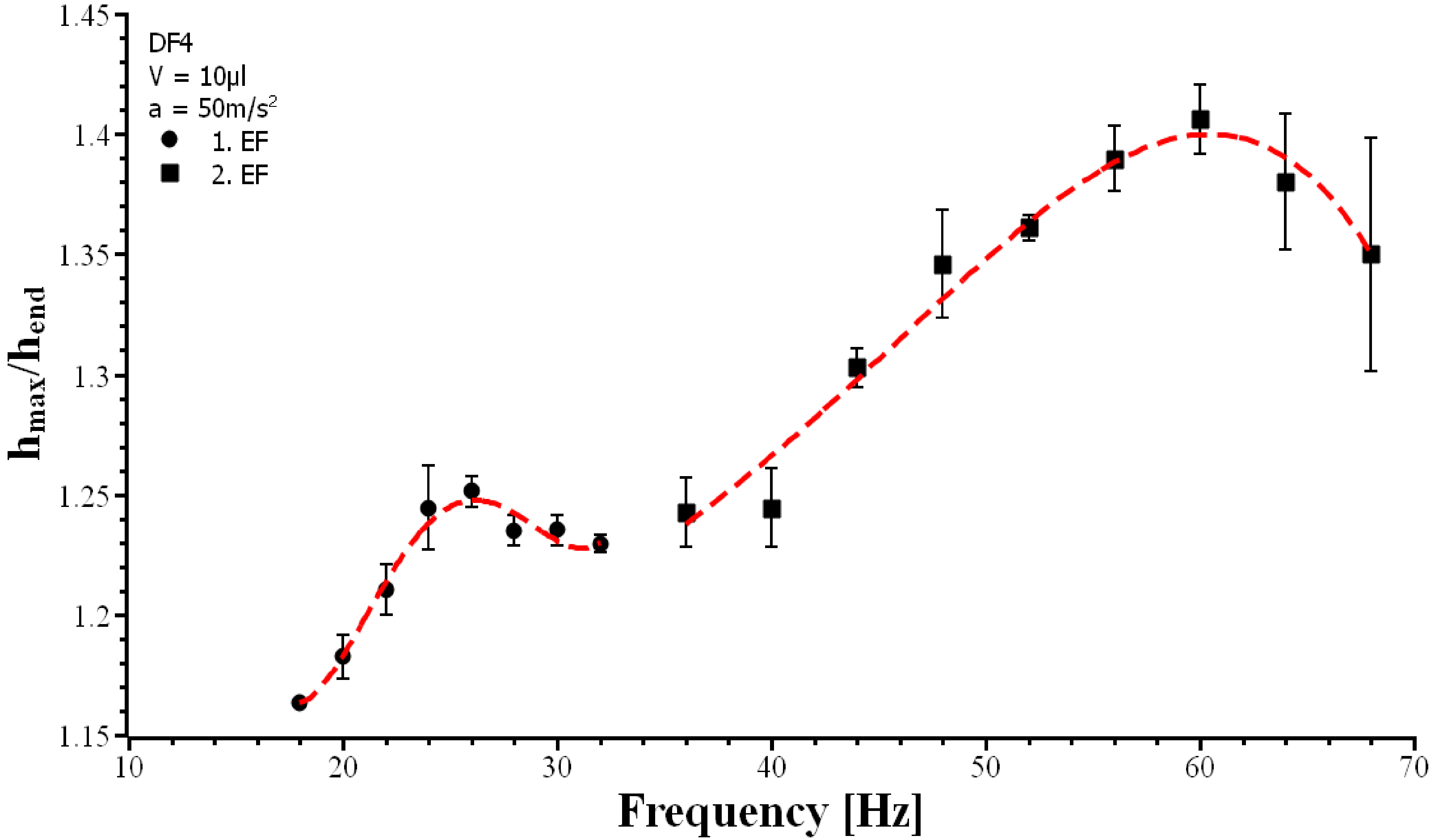
Results: Example vibration



Results: Eigenfrequencies

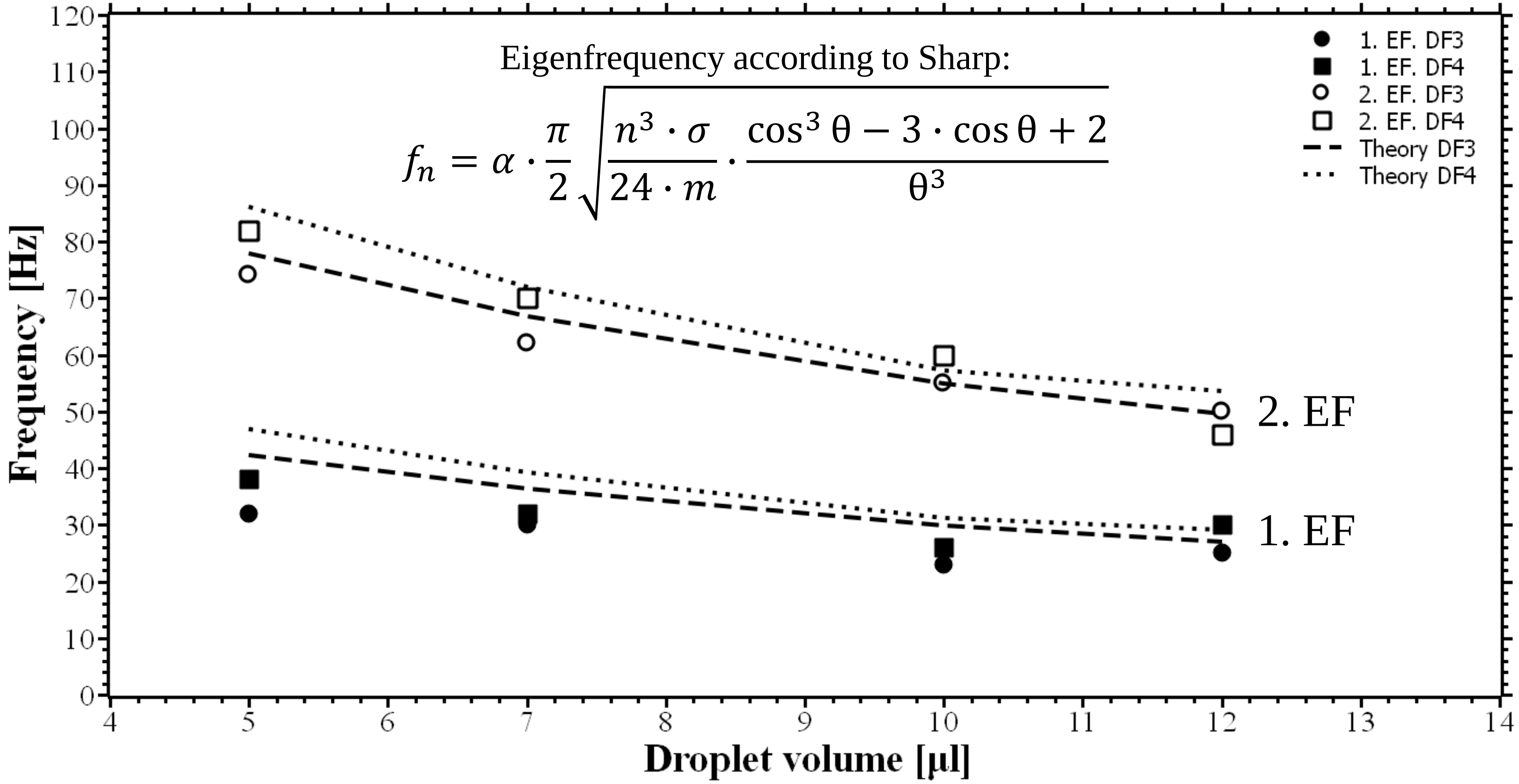
- Ratio: maximum drop height to drop height after excitation as a function of excitation frequency with the same acceleration
- Peak points correspond to the eigenfrequencies
- Tested on DF3 and DF4 with different drop volumes and accelerations
- No difference in eigenfrequency as a function of acceleration. Only the shape of the curve.



Results: Eigenfrequencies

- Eigenfrequencies are slightly below the theoretical solution
- For water $\alpha = 0.81$ is suitable for the first Eigenfrequency
- The deviation from the theoretical solution increases with increasing viscosity
- Better suited for oil: $\alpha = 0.74$
- Material properties at 20°C

Fluid	$\rho\ [\frac{kg}{m^3}]$	$\nu\ [\frac{mm^2}{s}]$	$\sigma\ [\frac{mN}{m}]$
Oil	854	41.991	33.504
Water	998	1.002	72.75



Results: Droplet drain DF3

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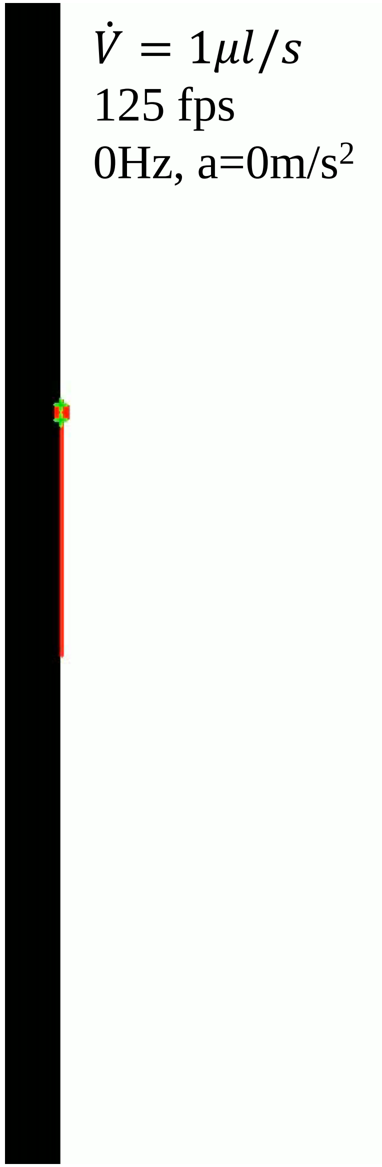
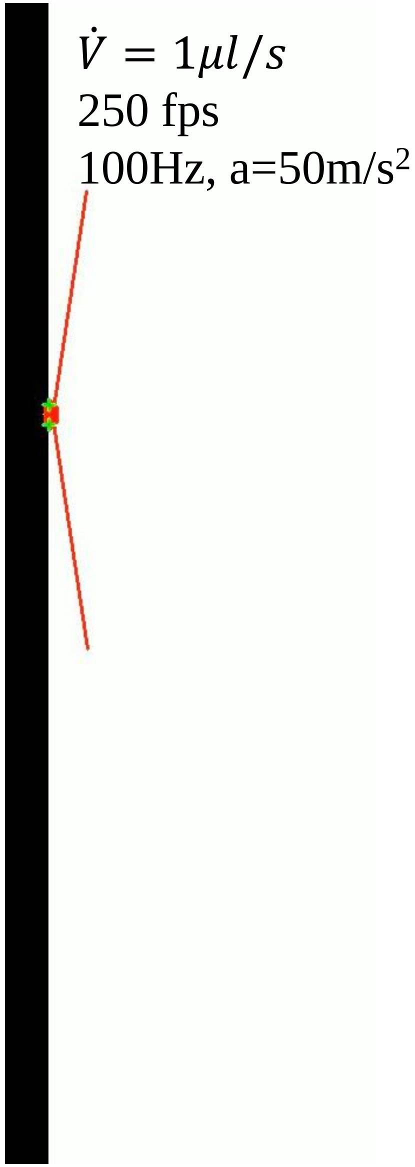
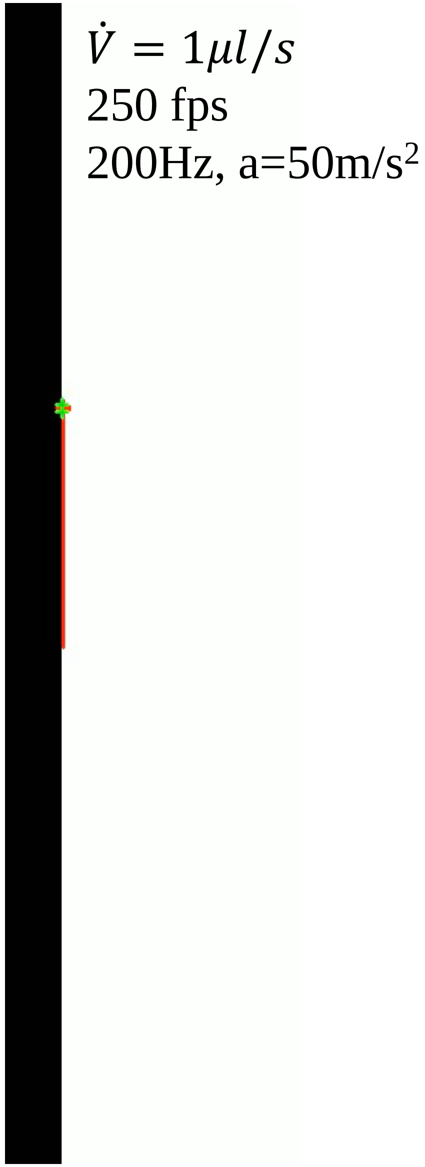
- Generation with pump
- Continuous volume flow
- Measurement of drop geometries during growth to drainage
- With and without excitation
- $t_{DF3} < t_{DF4}$ $(0Hz \approx 2 - 4s)$

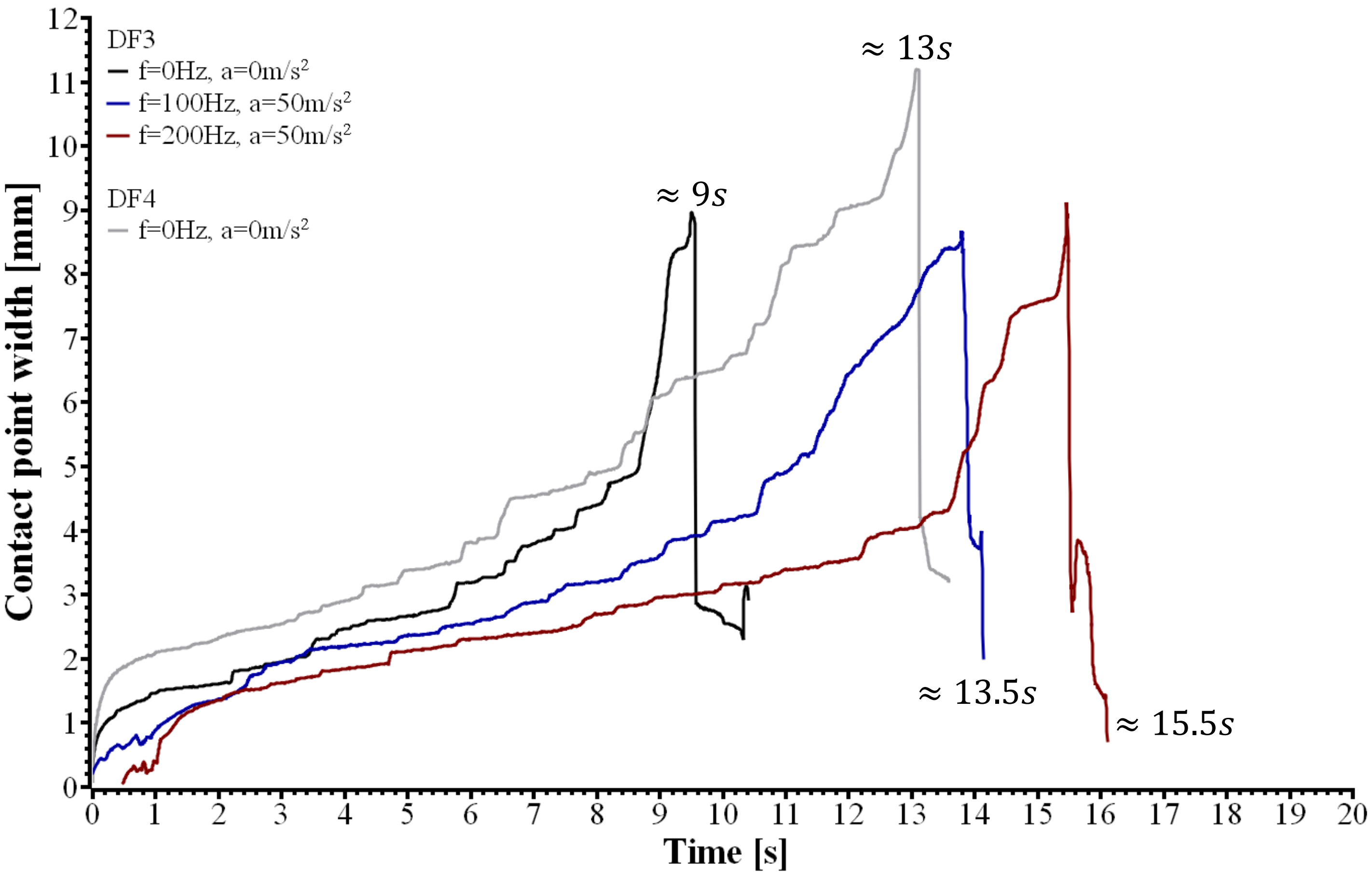






Results: Droplet drain

- Continuous volume flow until draining/detaching
- Measurement of drop geometries during growth to drainage
- Clear detection in case of detachment



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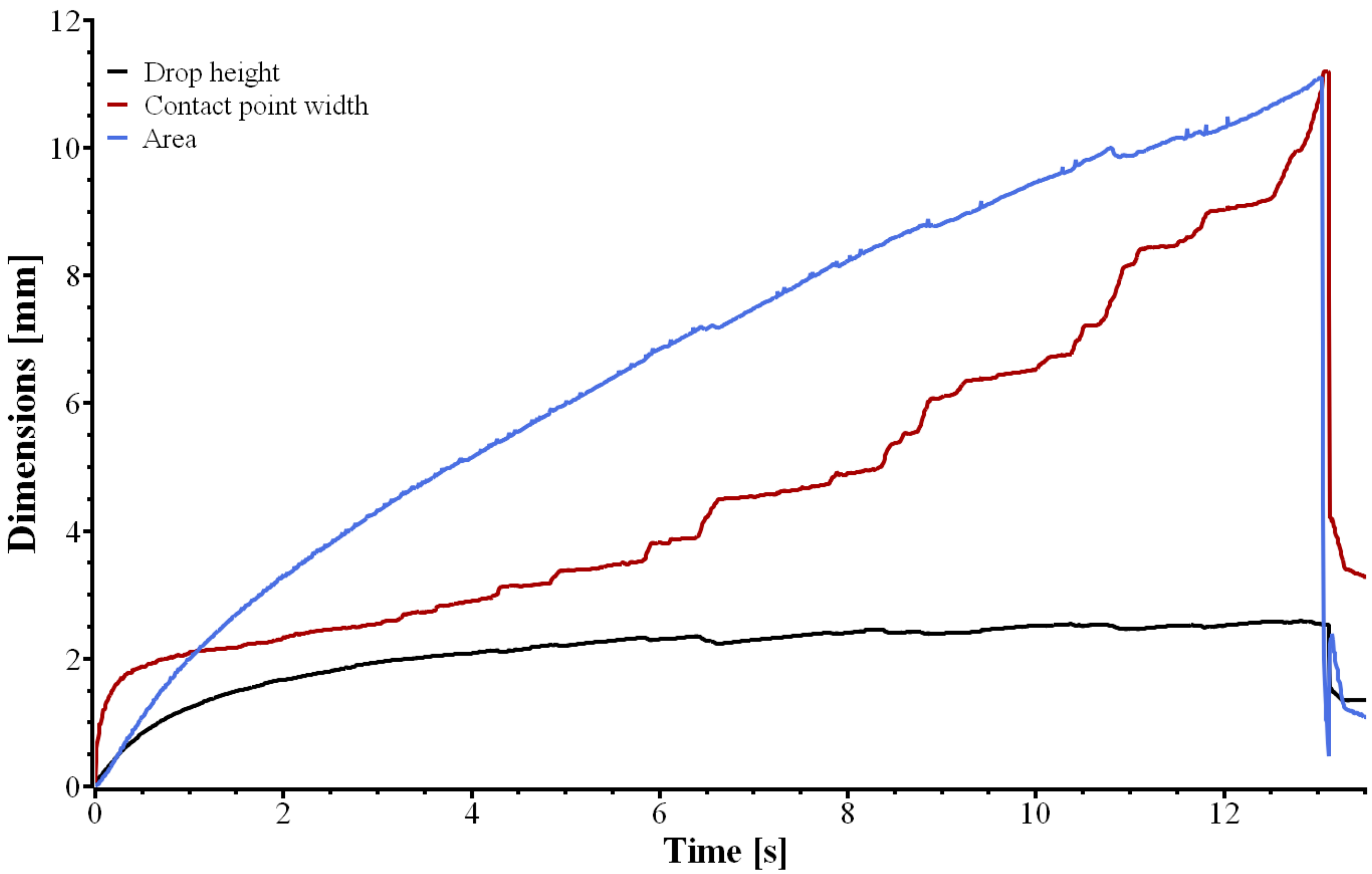
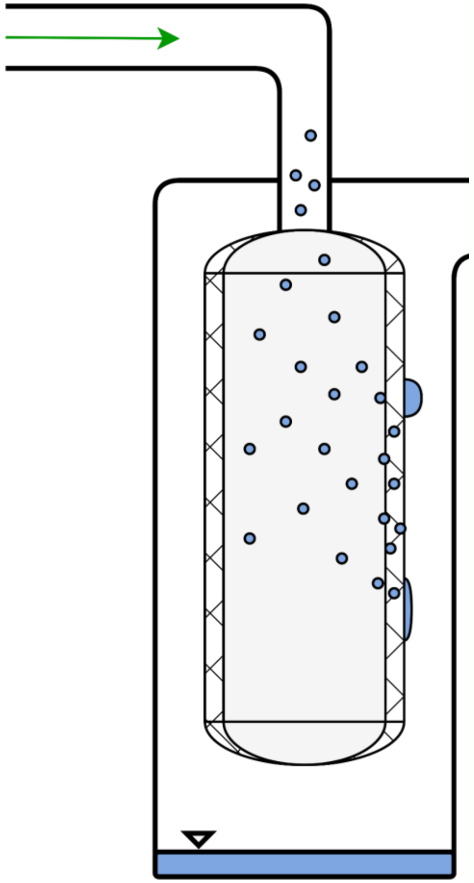
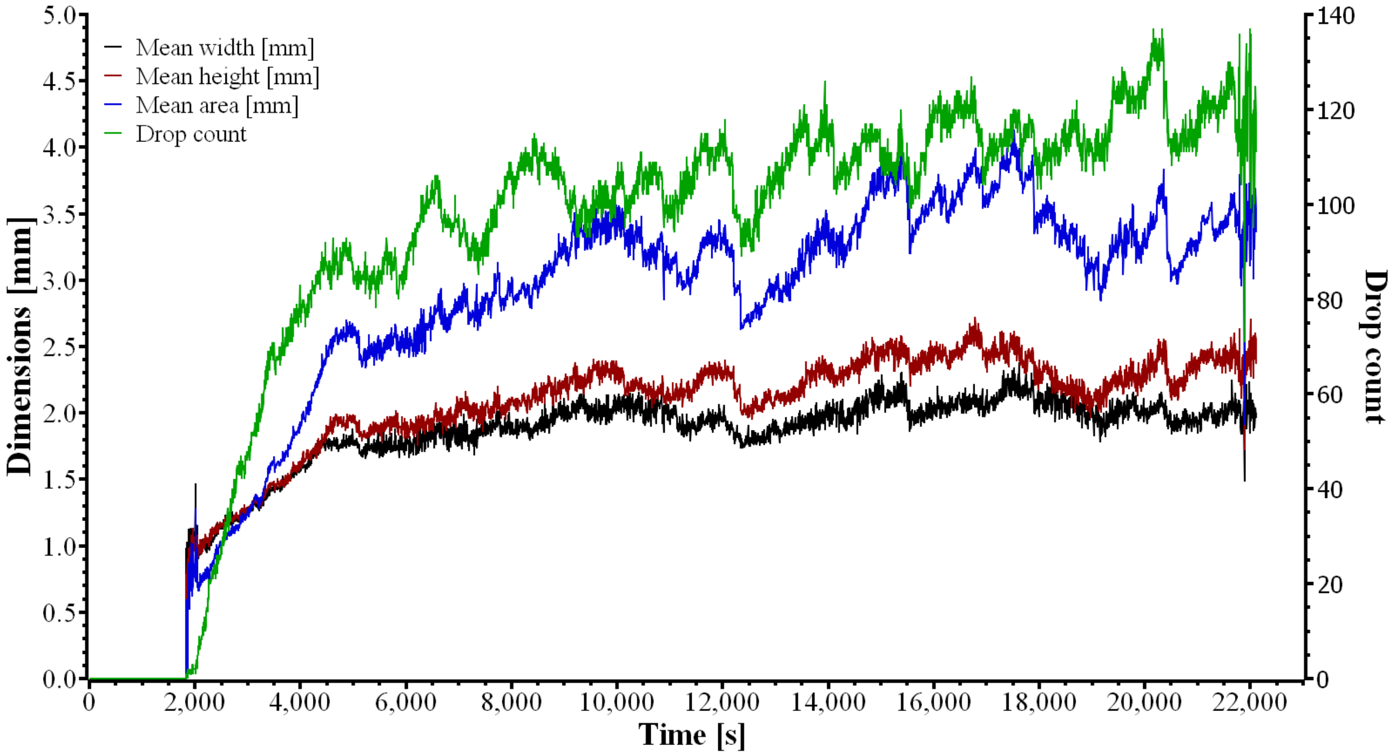


Filter chamber





Agenda

Summary and Outlook

Summary

- Change of oil: Shell Corena to Shell Ondina, because of significantly lower viscosity
- Droplet generation by pump (closer to real behavior)
- Determination of the 1st and 2nd natural frequencies
- Start of droplet tests under inclination with/without vibration

Outlook

- Drain with/without vibration
- Outlet with incident flow with/without vibration
- Pulsating flow
- Measurement of pressure drop with excitation
- Supplementary simulations using OpenFoam 8®

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Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages

Industrielle Gemeinschaftsforschung

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