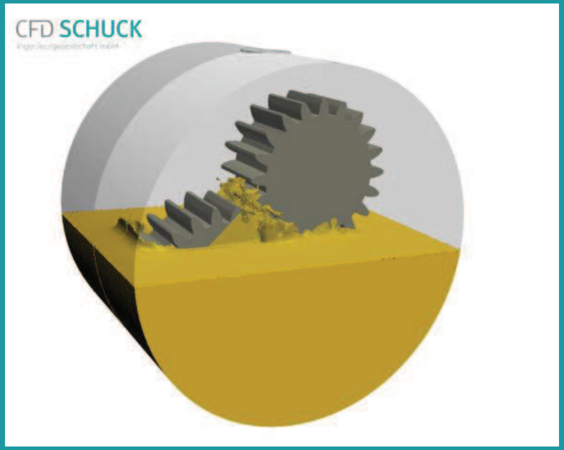
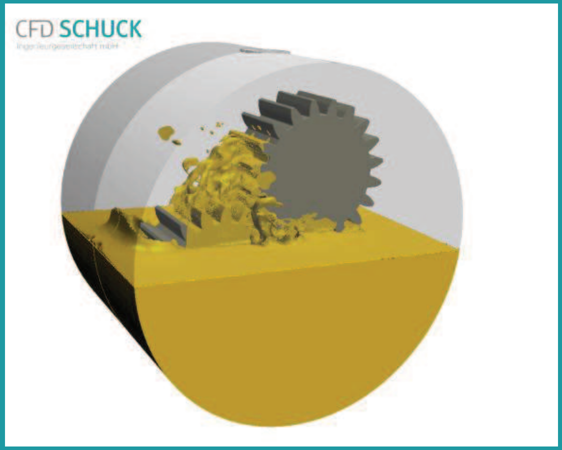
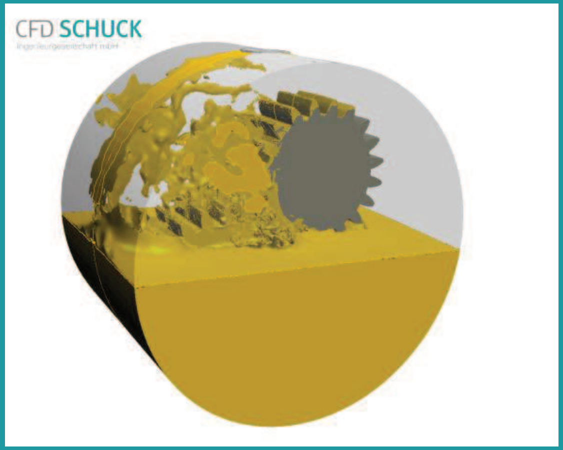
CFD SCHUCK
Ingenieurgesellschaft mbH

Coupled simulation of Multiphase Fluid Flow & Multiple Body Motion: Oil flow in a rotating spur-gear system







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Outline

1. Motivation

Gear lubrication is a significant concern in a wide range of industries which use power transmission.

Main objective of **CFD model prediction** is the optimization of the oil flow around rotating components in a gearbox:

- Improve the efficiency of transmissions
- Reduce the friction between the gearwheels (pitting)
- Minimization of load-independent spin power losses
- Assessment of wall effects on gear housing

➡

Reduction of the operation costs of a gearbox and prolonging the component lifetime.

2. Methodology

- **Multiphase Fluid Flow**
  - Volume Of Fluid (VOF) Method: utilizes an Eulerian framework
  - immescible fluid phases share velocity, pressure, and temperature fields
  - air entrapment and turbulence regimes can be well represented

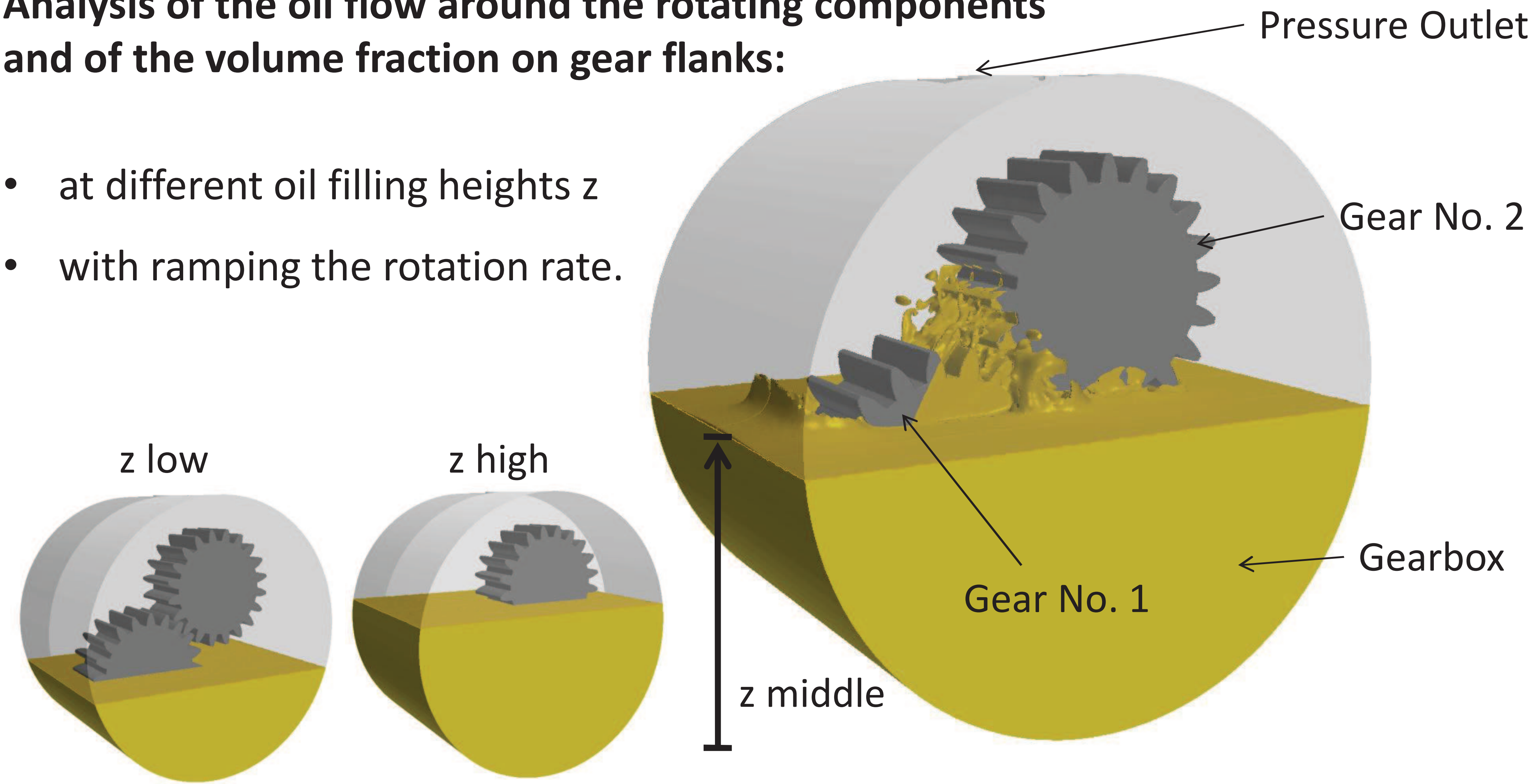
coupled with

- **Multiple Body Motion**
  - Overlapping Overset (Chimera) Method: Overlapping of multiple grids
    → every motion can be simulated
  - every moving body is represented with one grid
  - one mesh in the background which "contains" all meshes

3. Problem setup

Analysis of the oil flow around the rotating components and of the volume fraction on gear flanks:

- at different oil filling heights z
- with ramping the rotation rate.



3.2. Mesh generation

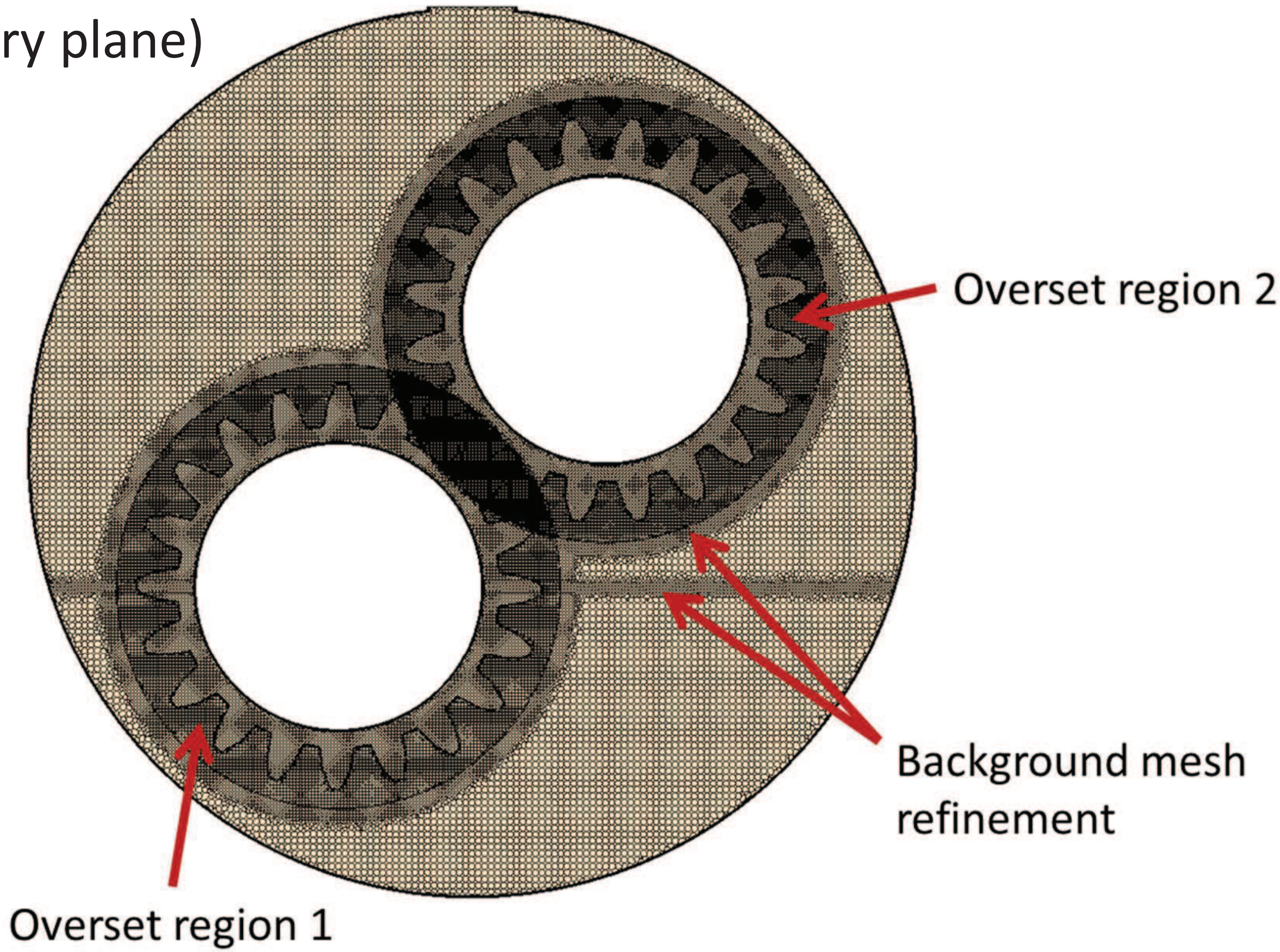
Geometry (incl. symmetry plane)

gear housing:
d = 280 mm
l = 200 mm

gear-wheels:
d = 130 mm
l = 58 mm

overset region 1,2:
d = 140 mm
l = 68 mm

background region
– mesh refinement:
d = 150 mm
l = 70 mm

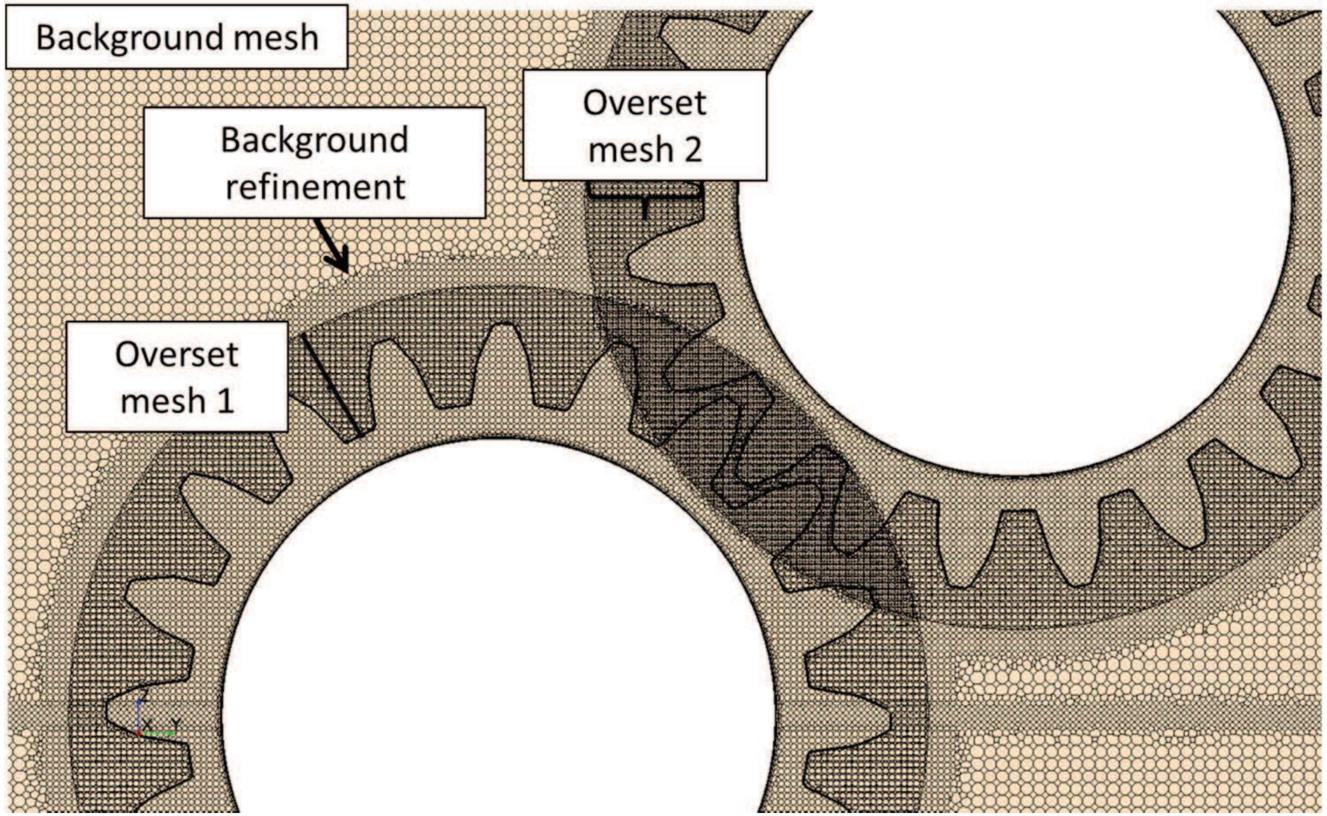


Mesh – detailed view

Polyhedral mesher:
- background region 2 mm, refinement 1 mm, intersection 0.5 mm
- overset regions 1mm

Prism layer mesher:
- 5 prism layers

➡ **≈ 5.4 mio cells**



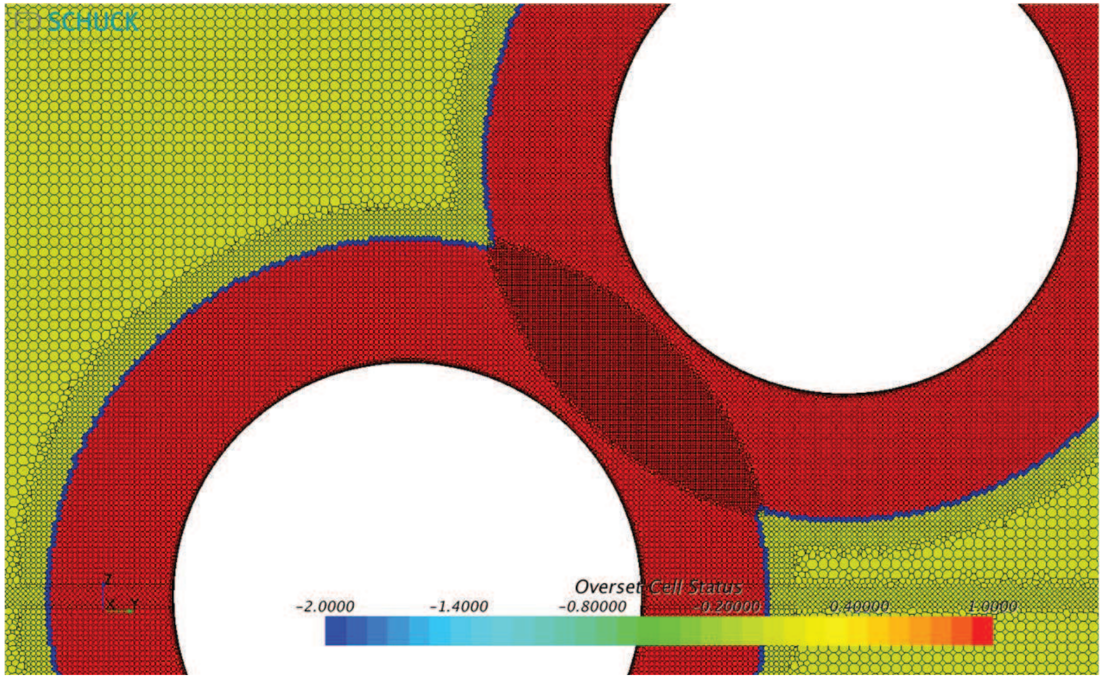
Simulation time requirements:

\# inner iterations 5
\# processors: 12

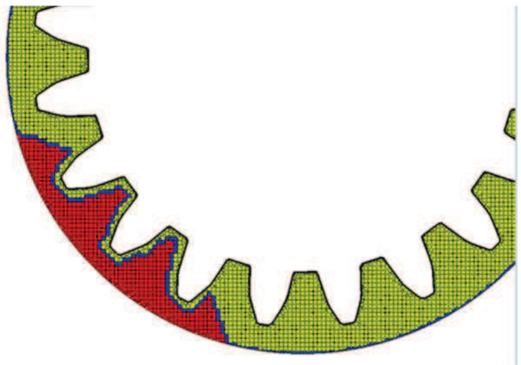
20 s per Δt & 1 mio. cells

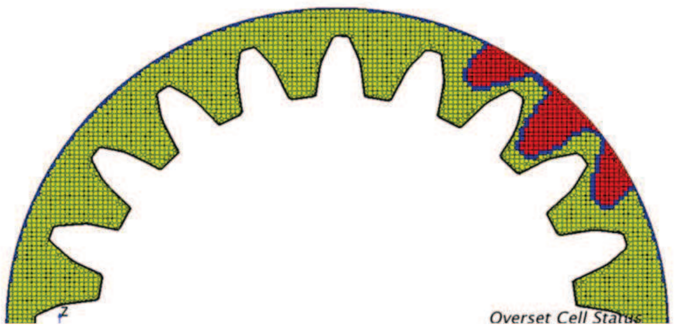
➡ **≈ 3.8 days per revolution**

Overset mesh – cell status



Active Cells
Passive Cells
Acceptor Cells





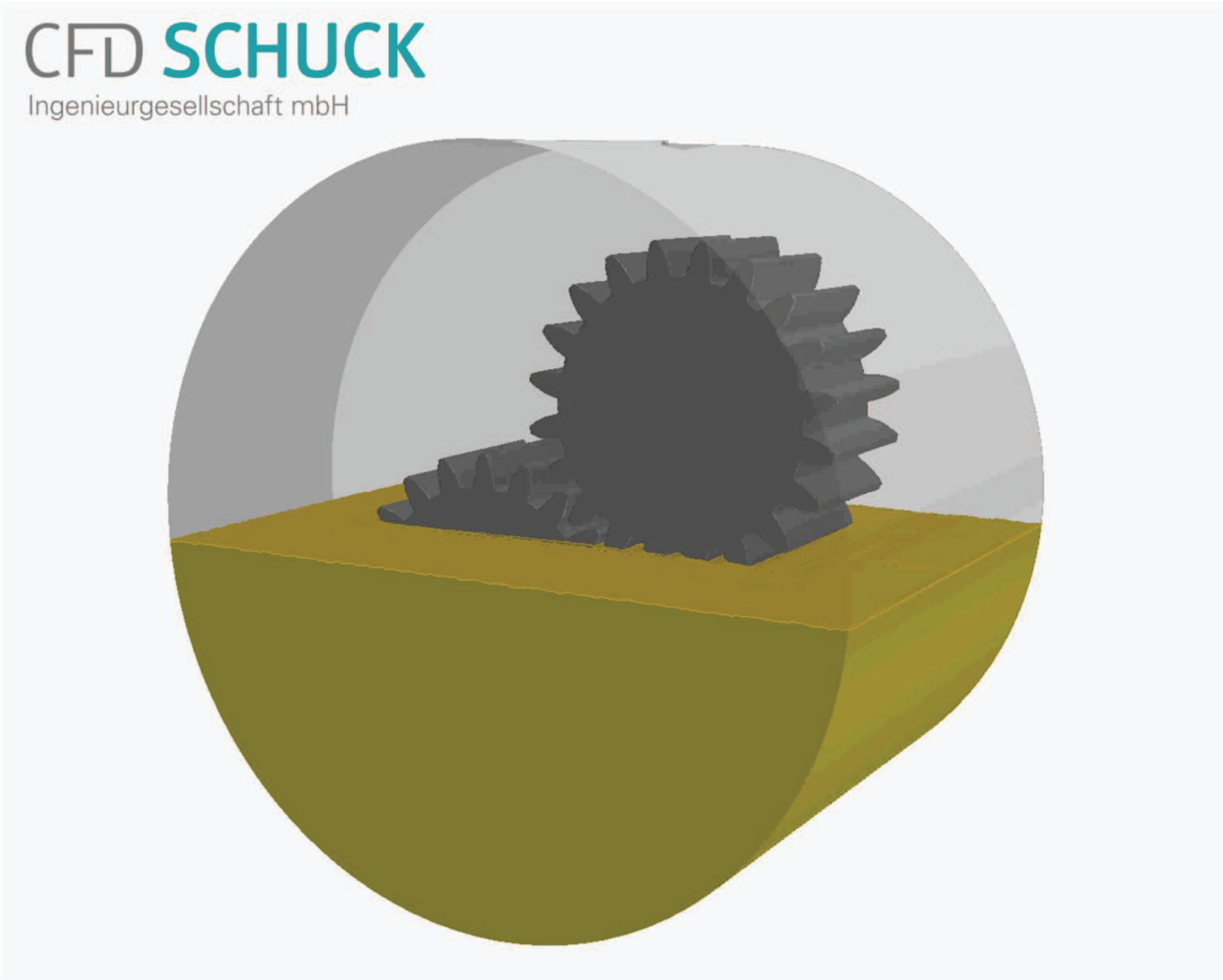
4. Modell setup

- Eulerian Multiphase Model isothermal
  - ➢ Volume Of Fluid: Phase 1 (gear lubricant)
    - – Oil (C12H26)
    - – density 841.2 kg/m^3
    - – dyn. viscosity 0.0149 Pa-s

    } ISO VG 220, 100°C

    Phase 2
    - – Air (ideal Gas)
  - ➢ Initial oil distribution by a user field function: z_{NORM} 0.35 / 0.457 / 0.564
- Multiple Body Motion:
  1. Rotation +/- 2000 rpm
  2. Ramping of the rotation rate by a user field function
- Turbulence Modell: k-omega SST (Menter)
- Solver Settings :
  - – Timestep $1 \cdot 10^{-5}$ s
  - – Inner iterations 5

5. Results

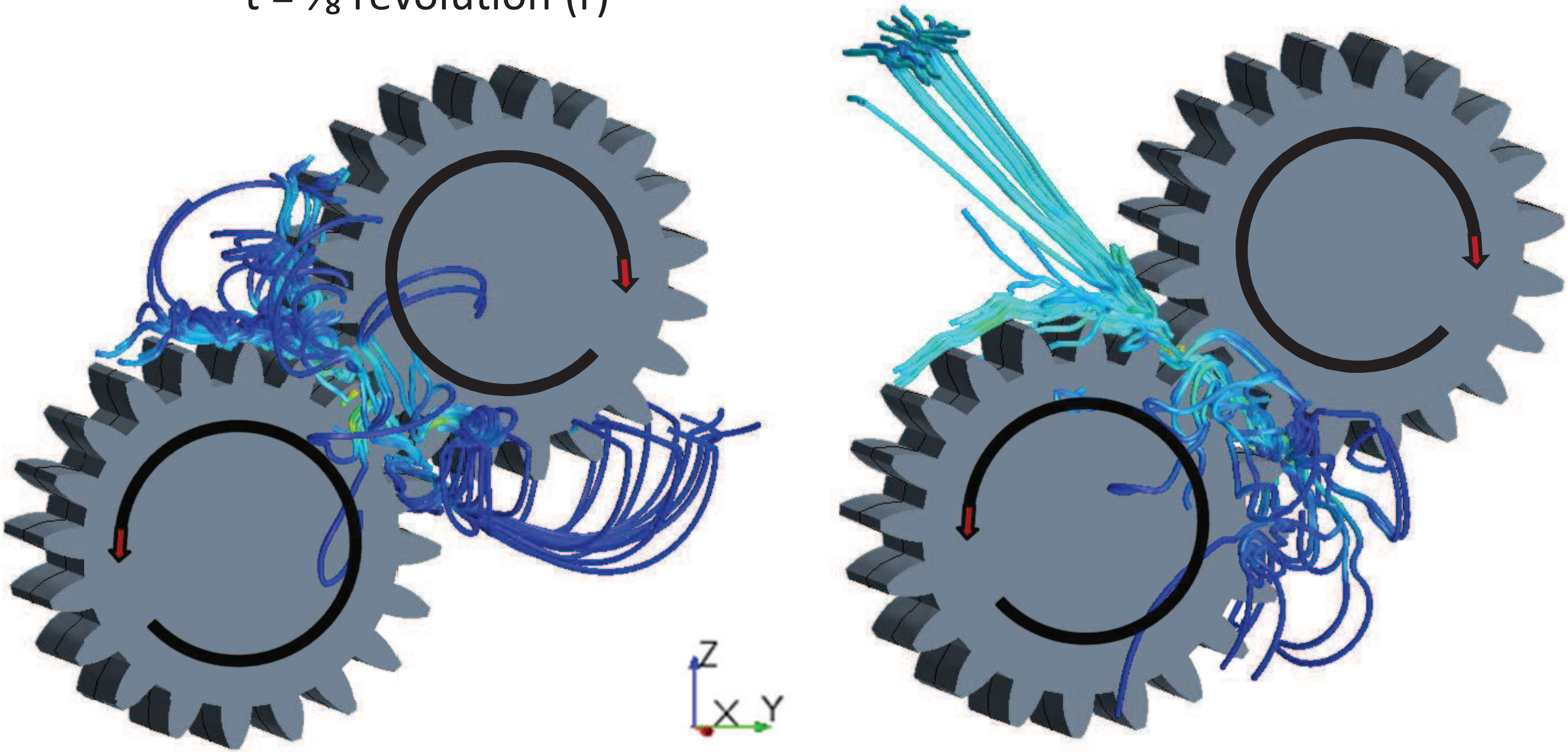


5.1. Flow fields transient (oil filling height middle)

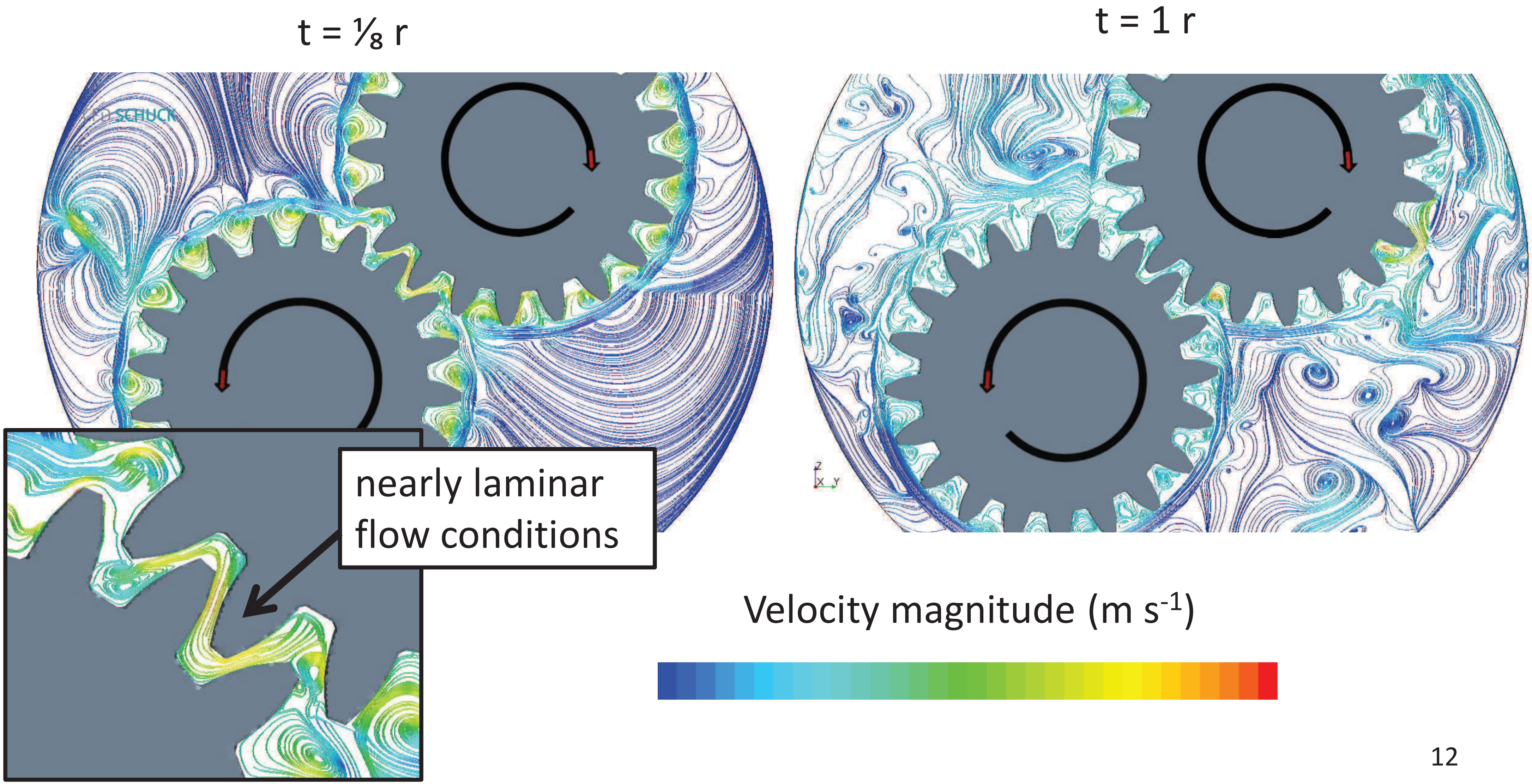
Velocity streamlines

t = ⅛ revolution (r)

t = 1 r

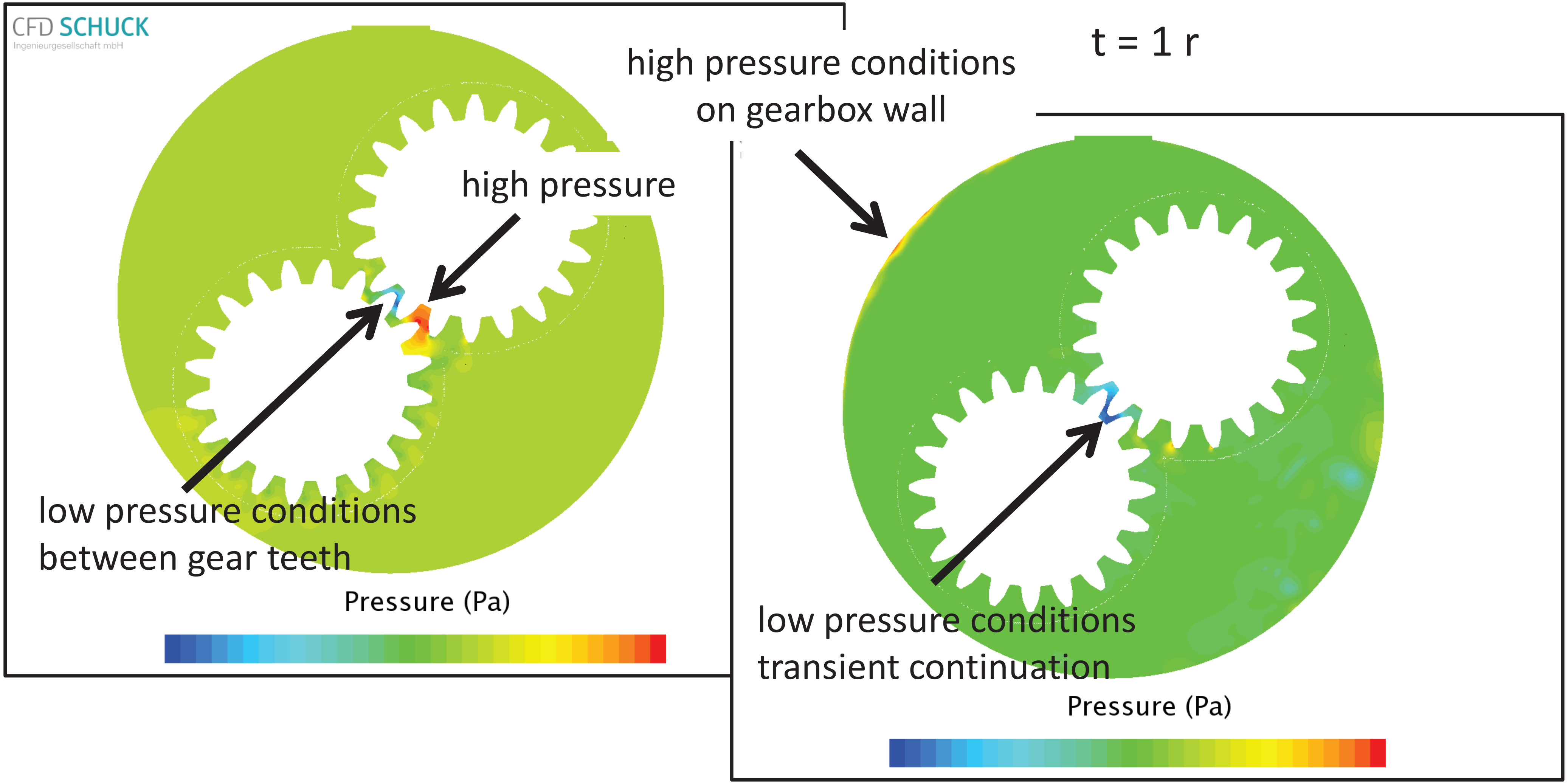


Velocity flow field (oil filling height middle)



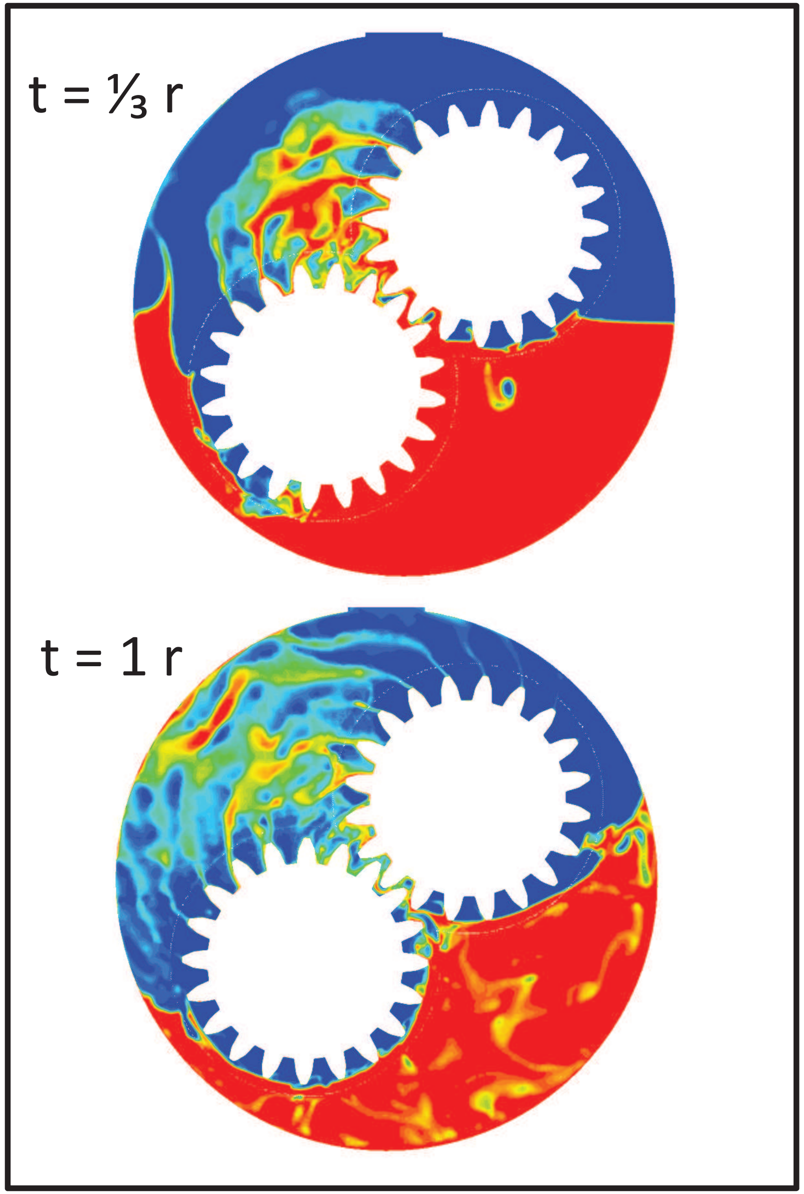
Transient pressure distribution (oil filling height middle)

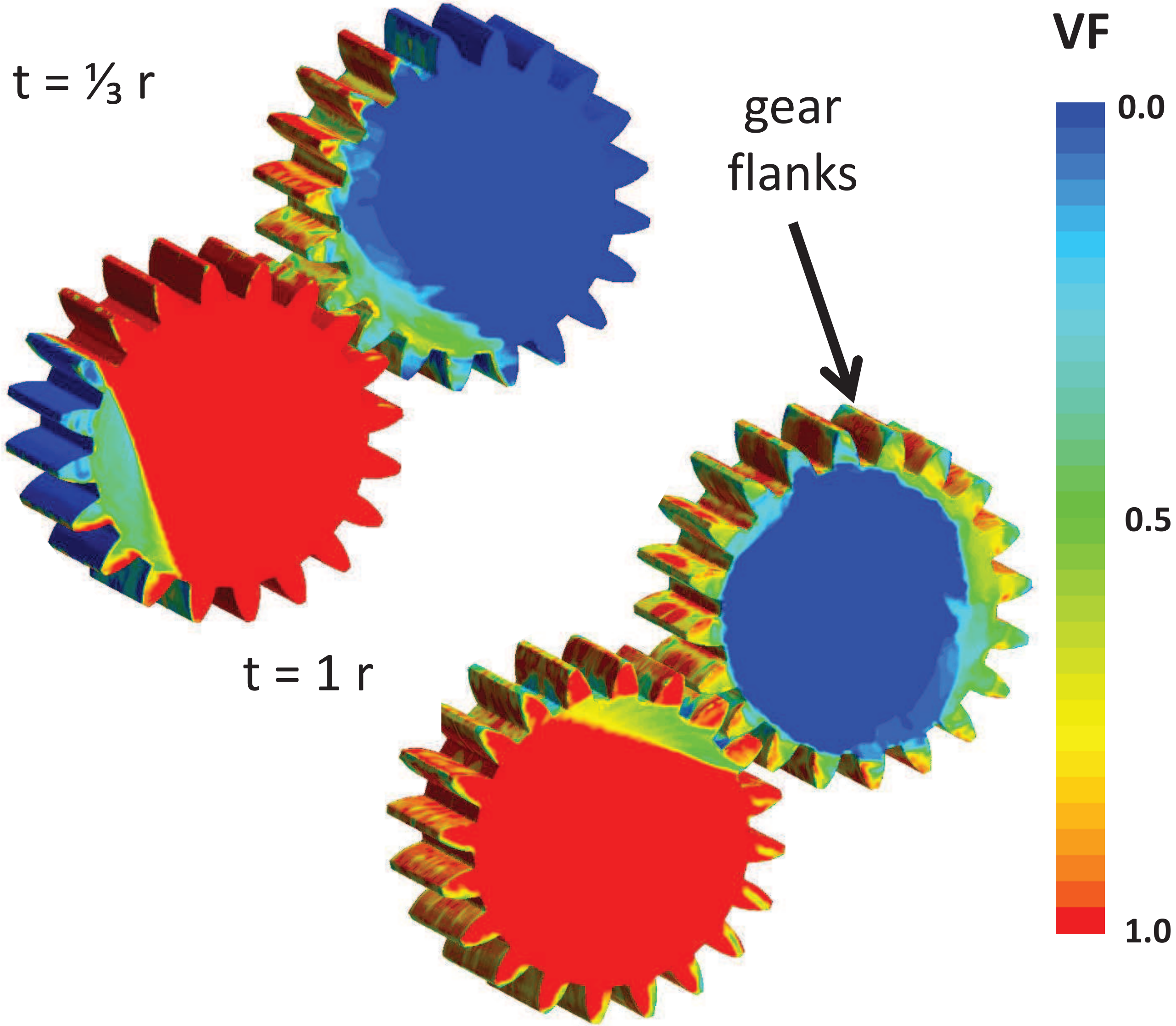
t = ⅛ r



5.2. Oil distribution in the box and on gear flanks

(filling height middle)

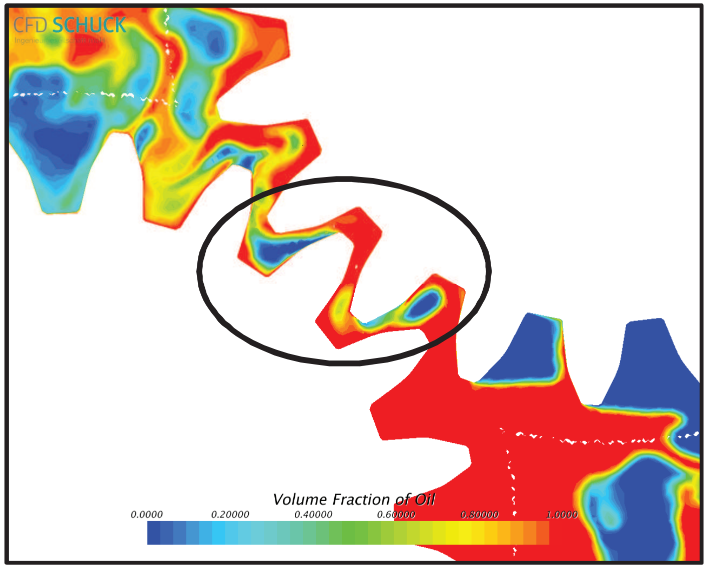




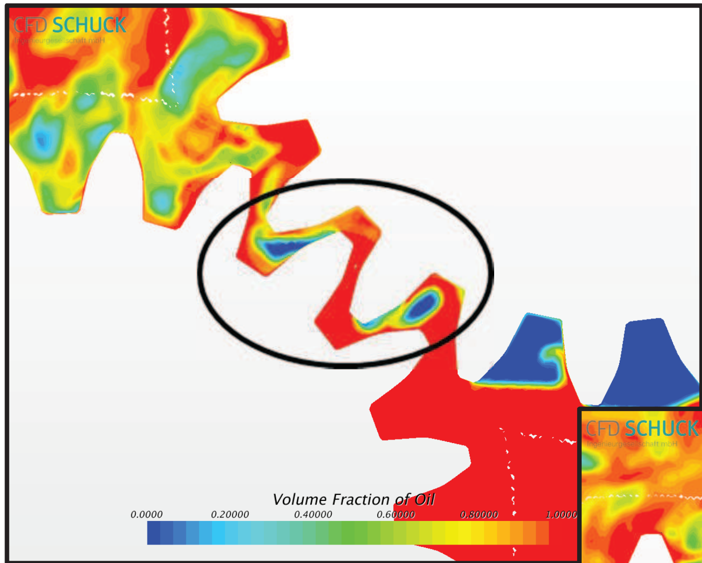
Volume Fraction (VF) of oil in interstitial gear regions

(comparison of different oil filling heights)

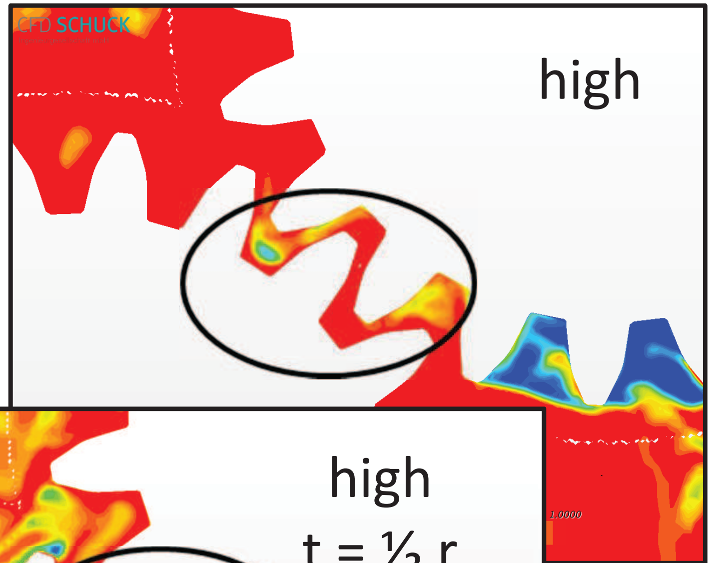
t = ⅓ r

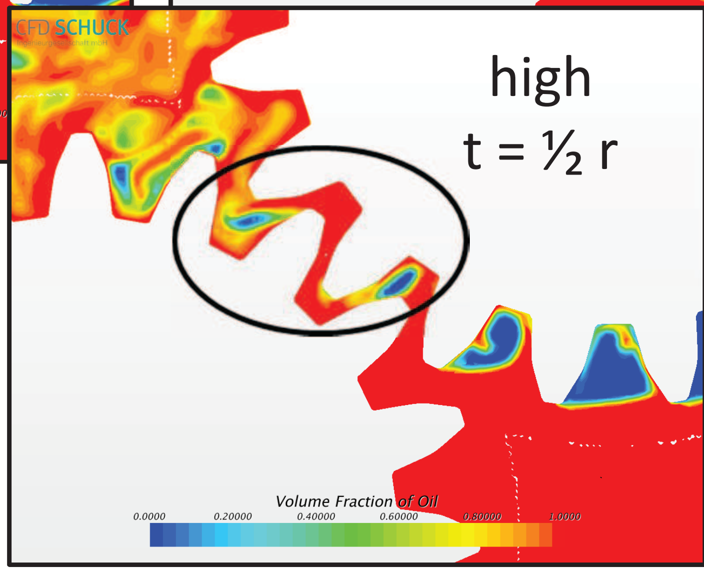


low



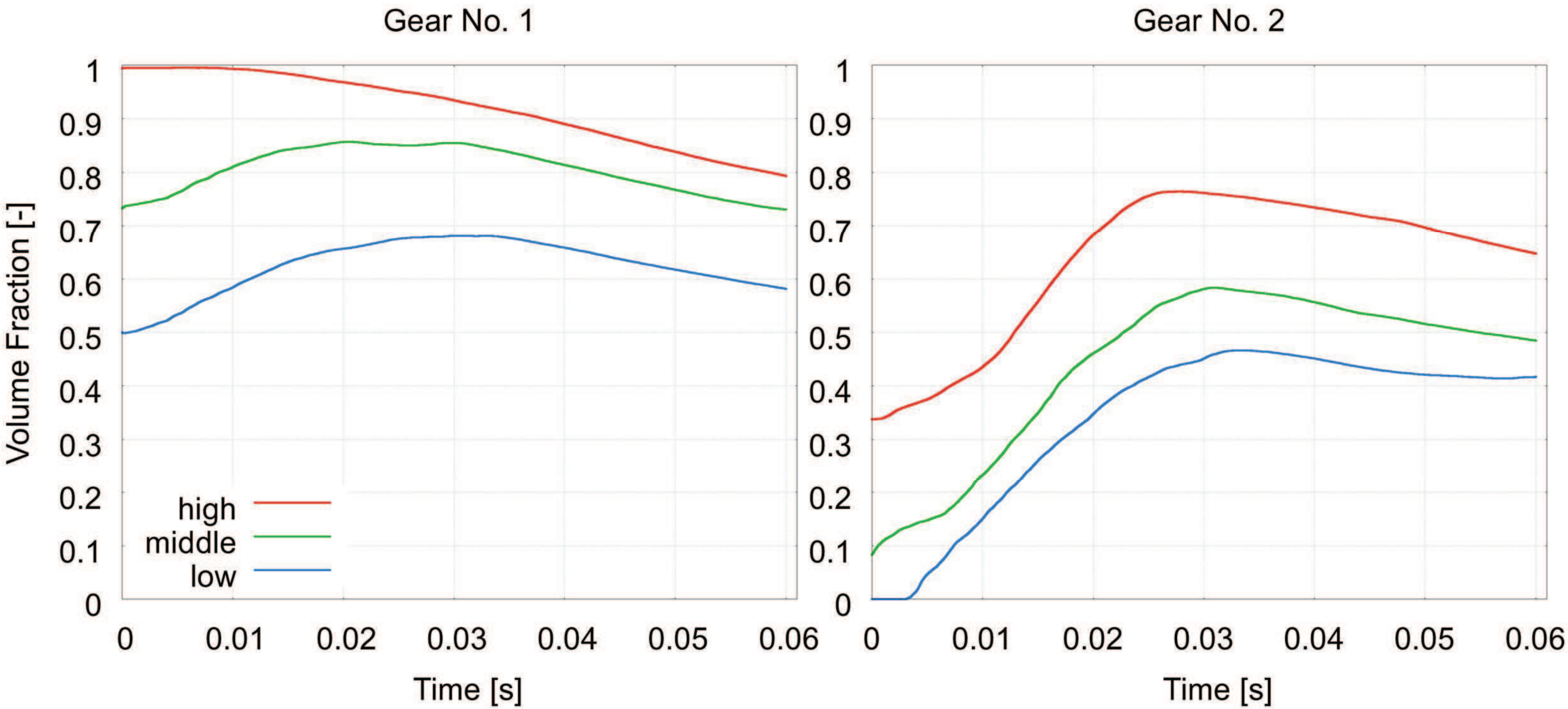
middle



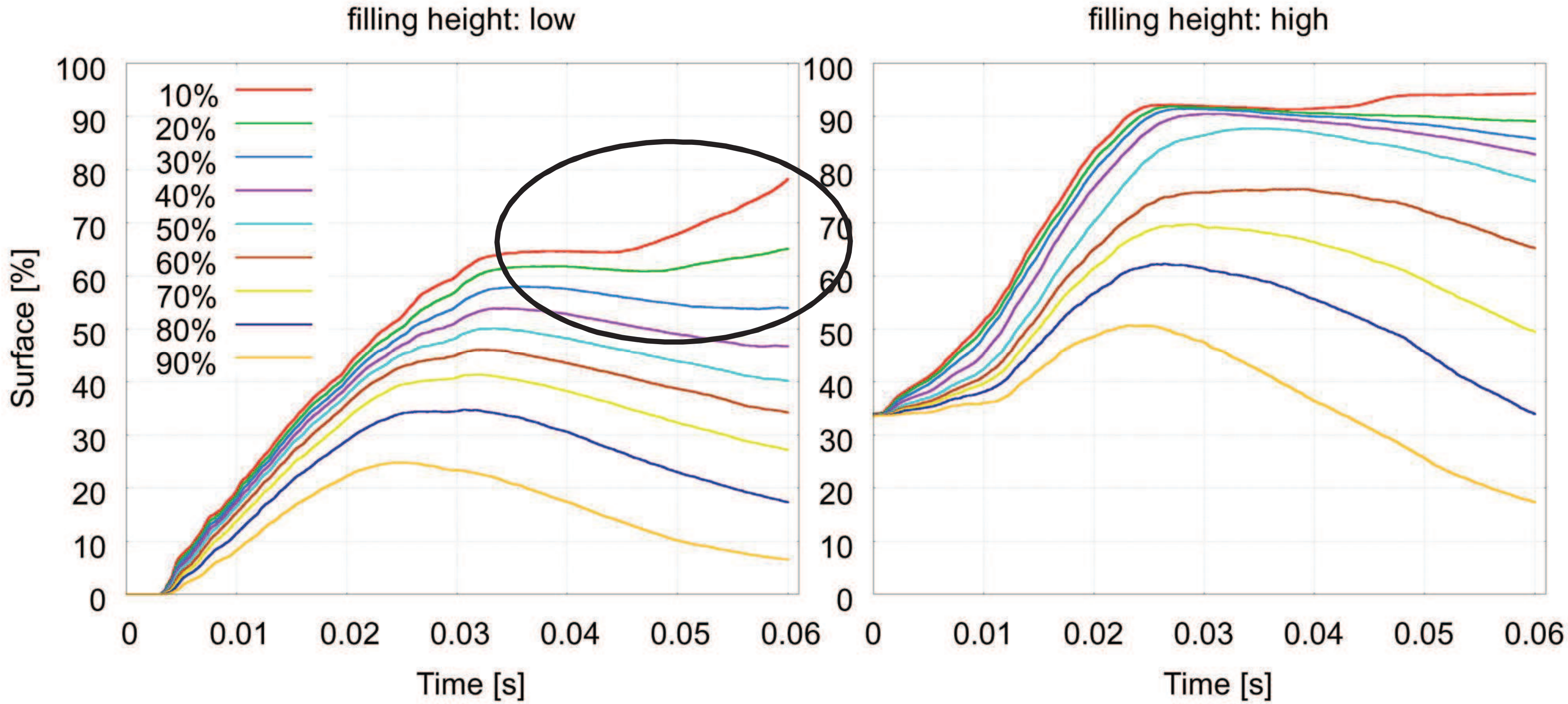


➡ inclusion of air bubbles in interstitial gear regions in all cases

VF of oil on gear flanks
(comparison of different oil filling heights)

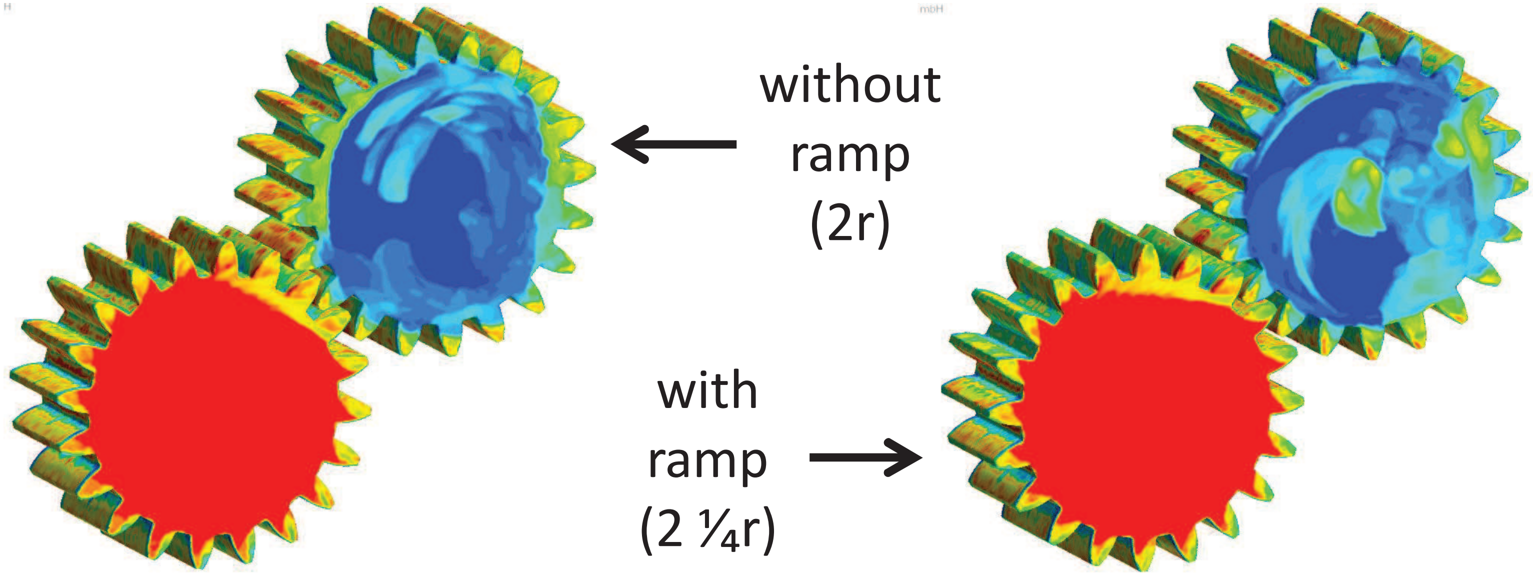


VF of oil in detail on flanks of gear no.2



	oil filling [%]	avg. pressure in gearbox (1r -2r) [%]	torque (at 2r) [%] G1	G2	friction (at 2r) [%] G1	G2	displaced oil volume (at 2r) [%]
low	32	100	100	100	100	100	4.5
middle	46	+ 18	+ 233	+ 141	+ 72	- 13	4.2
high	58	+ 34	+ 455	+ 497	+ 272	+ 59	8.9

5.3. VF of oil on gear flanks – Comparison with ramping the rotation rate



	oil filling [%]	VF on surface (≈ 2r) [%] (1st case as reference)	torque (≈ 2r) [%] G1	torque (≈ 2r) [%] G2	friction (≈ 2r) [%] G1	friction (≈ 2r) [%] G2	displaced oil volume (≈ 2r) [%]
2000 rpm	46	100	100	100	100	100	4.2
Ramp + 2000 rpm	46	- 4	- 2	- 2	- 6	- 4	4.4

6. Conclusions

1) **Transient flow fields, pressure, and torques in the gear-box and between adjacent gear teeth could be effectively studied by the presented CFD method.**

2) **The applied method was definitely convenient to study the influence of different oil filling heights:**
   - **on the oil flow in the gearbox**
   - **on the volume fraction of oil on gear flanks.**

3) **Ramping the rotation rate has in the present analysis no influence on the oil fraction on gear flanks.**

Outlook

1. **Inclusion of oil temperature simulation**
   - **heat dissipation in the gear-box**
   - **heat conduction at the gear-box wall**
   - **heat conduction at the gear flanks.**

2. **Influence of oil viscosity on oil flow and volume fractions on gear flanks.**

3. **Influence of gear-box design and gear wheel geometry.**

Thank you for attention!!