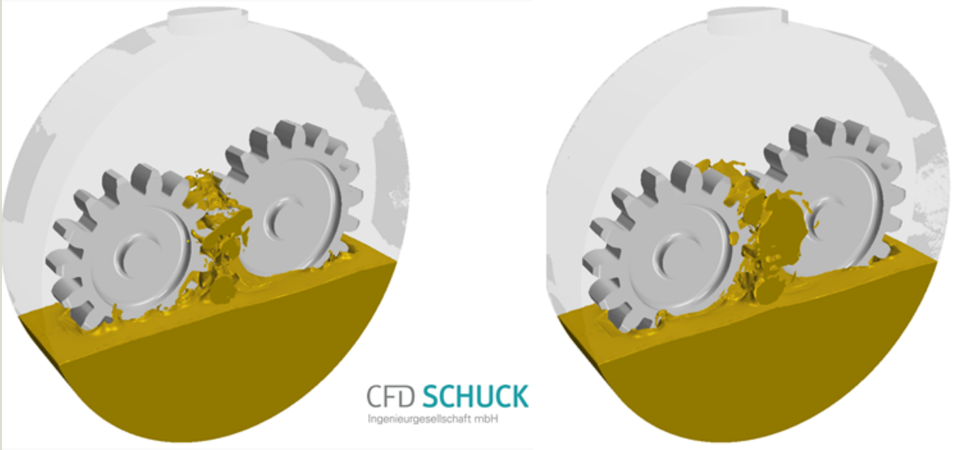
HIGH-END GEARBOX SIMULATION: MODELLING GEAR CONTACT WITH “ZERO GAP INTERFACES” ON A MULTIPHASE SPUR-GEAR SYSTEM

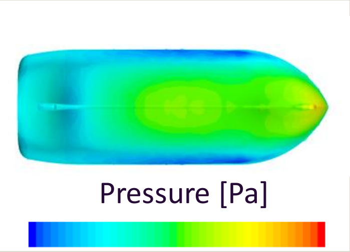


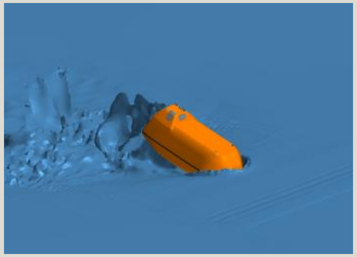
Vignesh Manian, Torsten Würfel, Christine Klier, Kathleen Stock, Ludwig Berger

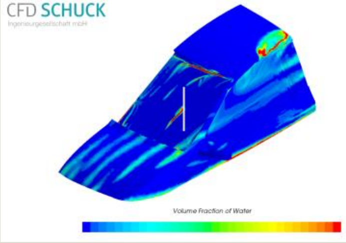
CFD SCHUCK ENGINEERING

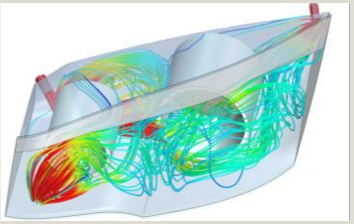
- Engineering Services in computational fluid Dynamics (CFD)
  - 25 employees at 3 locations in Germany

- more than 25 years of experience
  - established in Heidenheim in 1990
  - offices in
    - Munich (1999)
    - Gaimersheim (2014)









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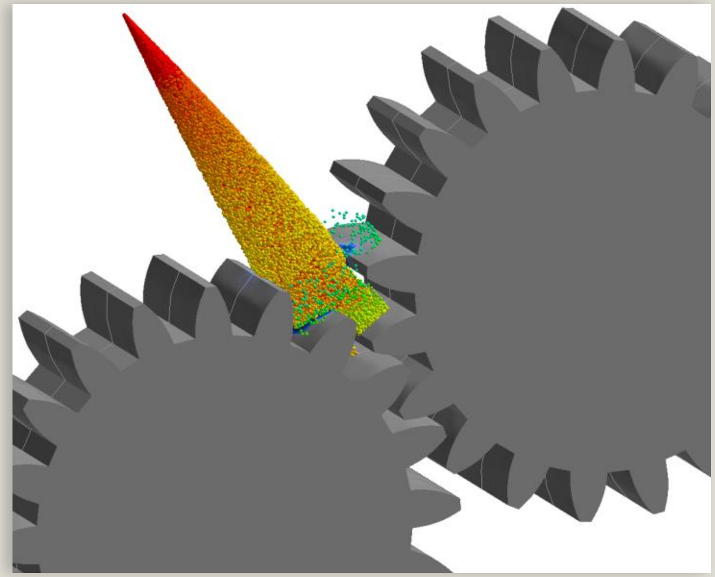
OUTLINE

1. Motivation
2. State of the art „Gear Simulation“
3. Modelling Setup and Mesh
4. Results
5. Conclusions and Outlook



1. MOTIVATION

Gear lubrication poses a significant concern in various industries.

Prototype testing does not always provide the information detail required.

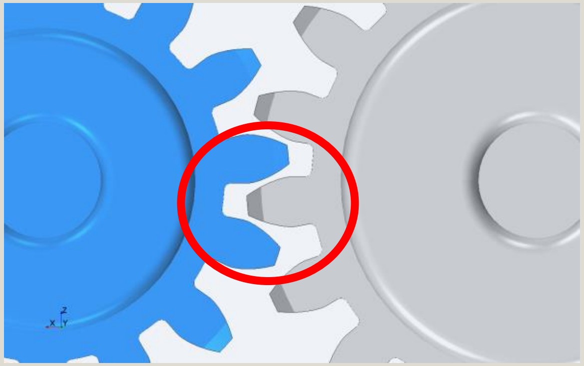
→

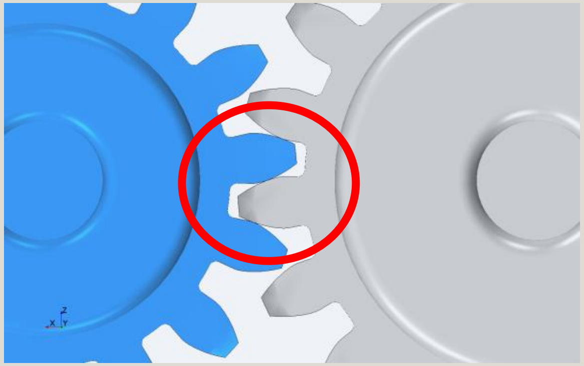
CFD model prediction is an effective tool for analysing oil injection systems and oil flow around rotating components in a gearbox:

- Improve the efficiency of transmissions
- Minimization of load-independent spin power losses
- Assessment of wall effects on gear housing
- Thermal management

1. MOTIVATION

- Current methodology simplifies contact modeling for gear system investigations
- Options:
  - repositioning of the gears
  - down scaling of the geometry
- Accurate investigation of gear systems requires contact modelling closer to reality





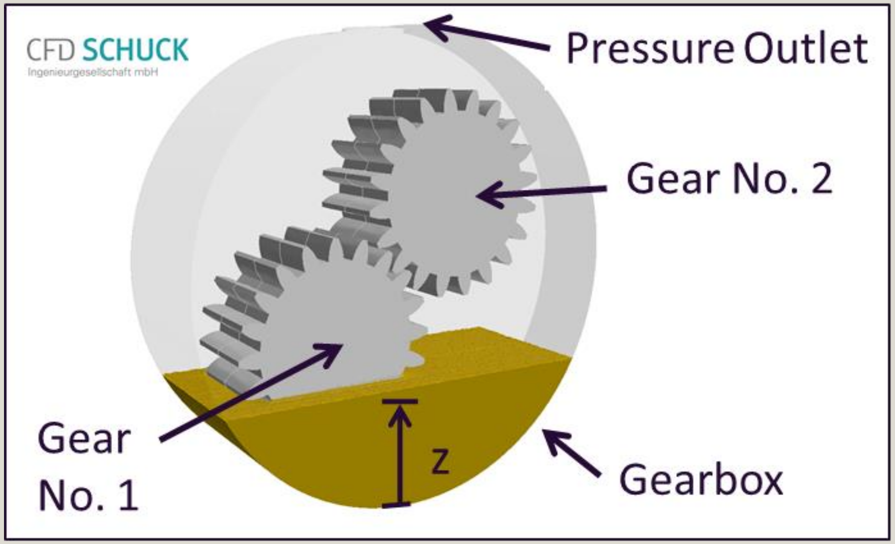
2. STATE OF THE ART (NO CONTACT MODELLING)

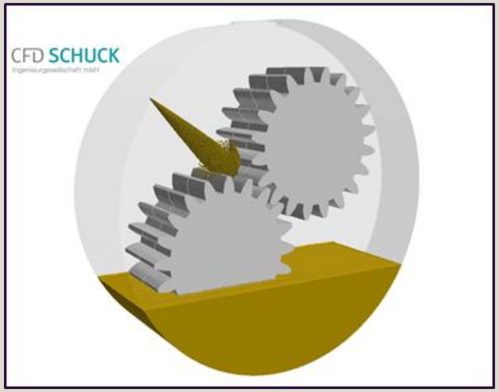
Spur-gear system of 2 gears with rotation rate of 2000 rpm

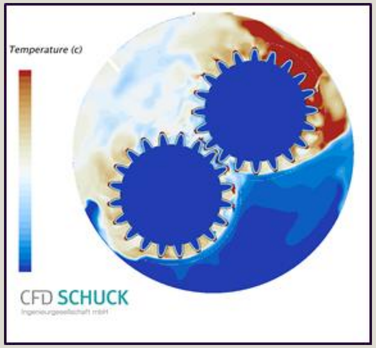
Var. 1: Oil sump – different filling levels

Var. 2: Oil sump and injection system

Var. 3: Oil sump and heat transfer

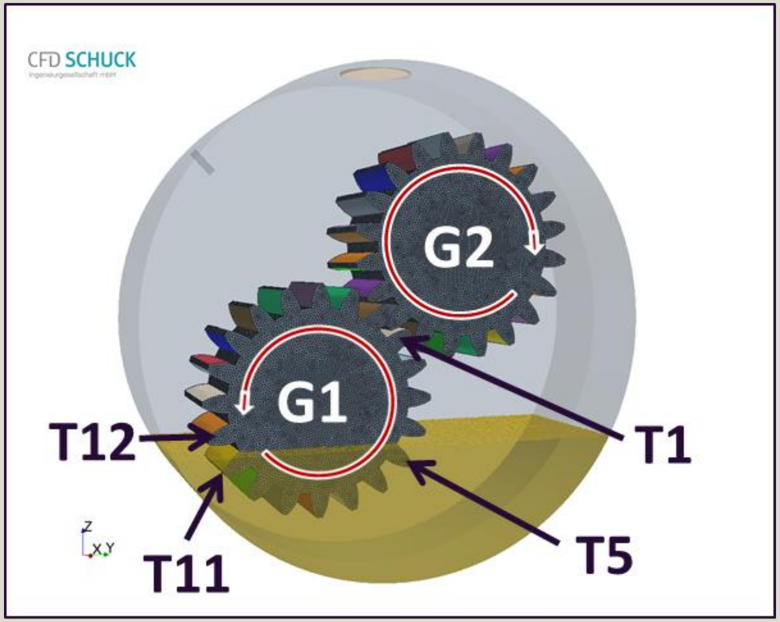


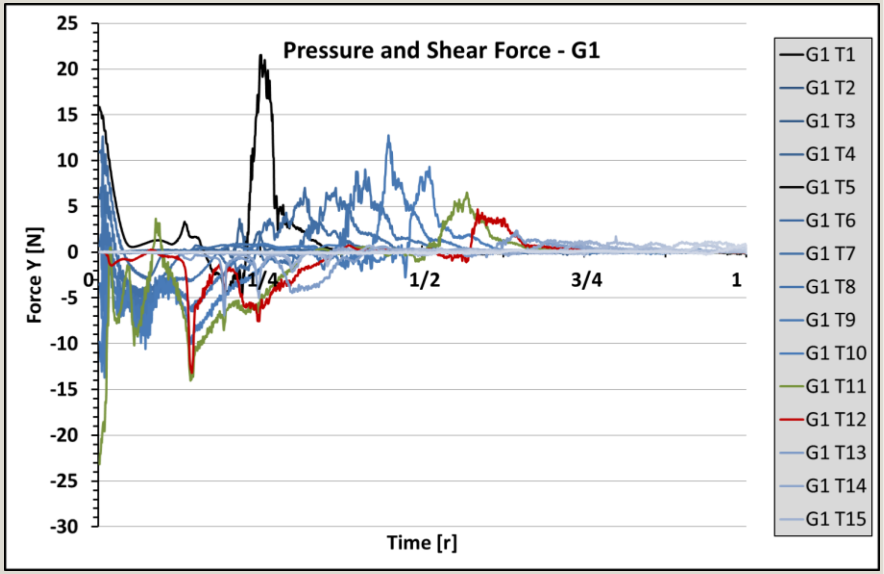




2.1. OIL INJECTION SYSTEM (VAR. 2)

FORCES FLUID EXERTED ON GEAR 1 SURFACE



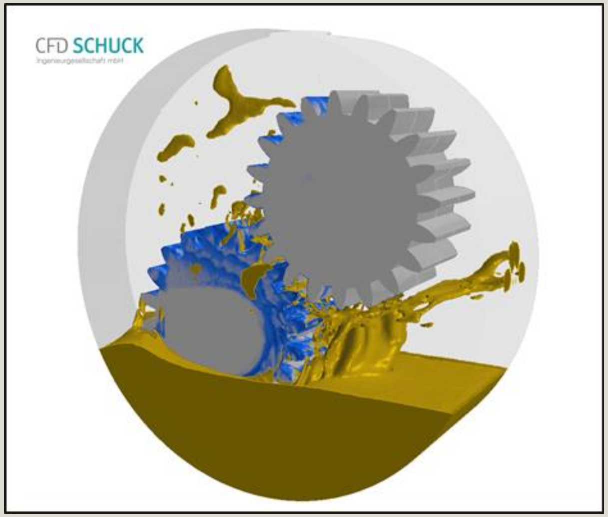


$$\overrightarrow{F_{pres\ y}} = (p_y - p_{ref}) \cdot \vec{a}$$

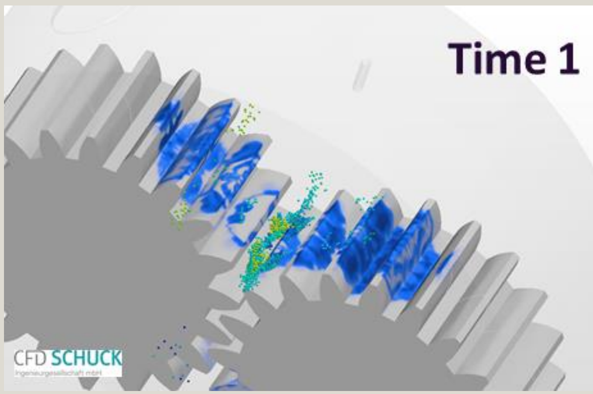
p_y face stat. press.
a face area vector

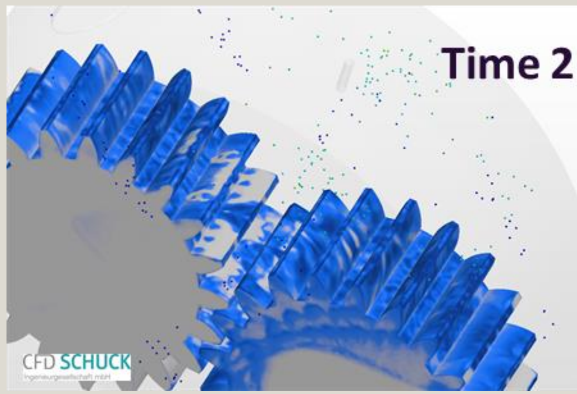
$$\overrightarrow{F_{shear\ y}} = -\ T_{shear} \cdot \vec{a}$$

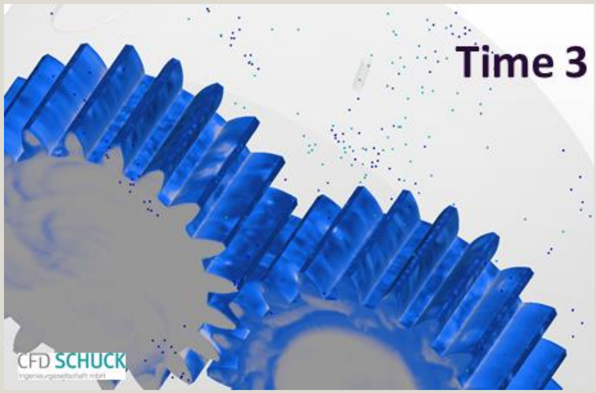
T_{shear} shear stress tensor

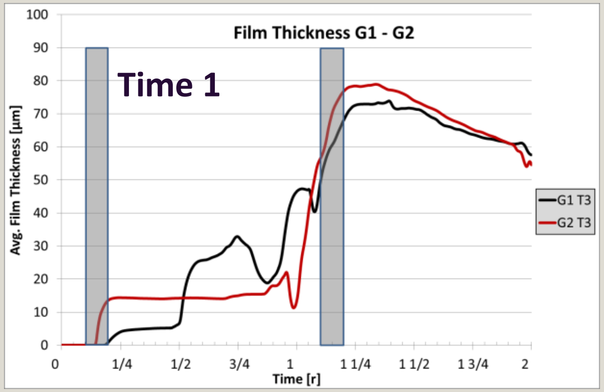


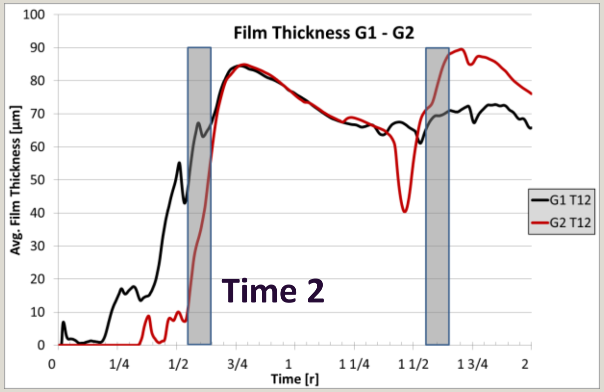
2.3. FLUID FILM THICKNESS ON GEAR TEETH (VAR. 2)

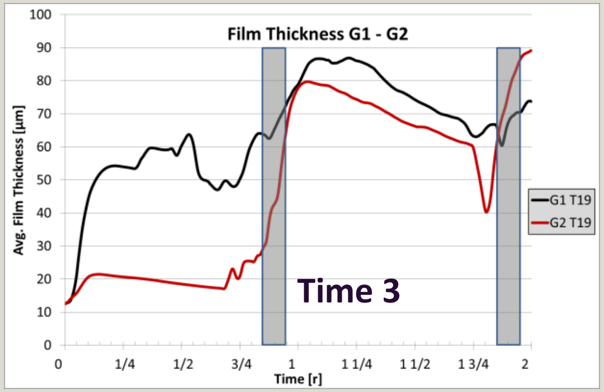






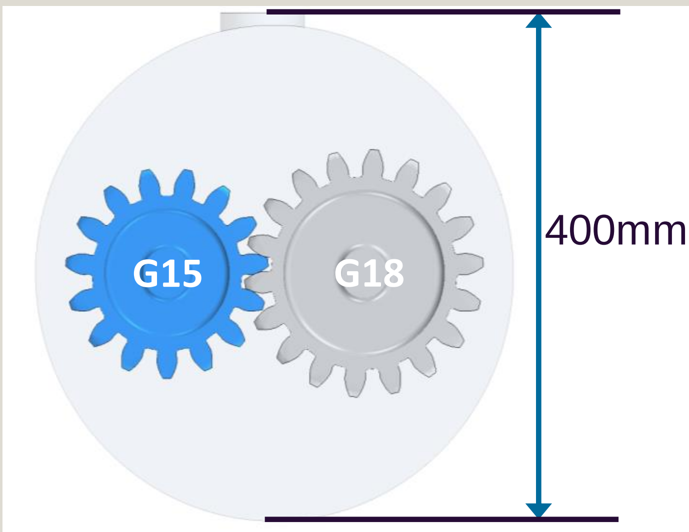


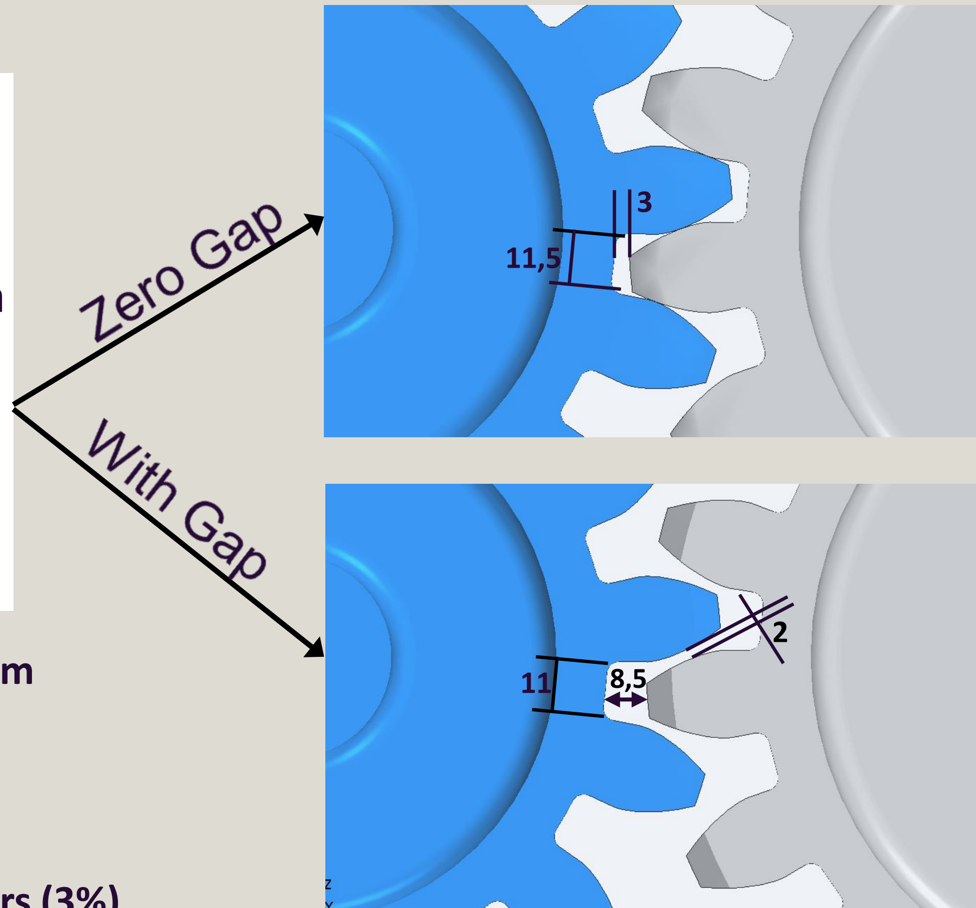




3. MODELLING SETUP AND MESH

3.1 GEOMETRY (HALF MODEL)

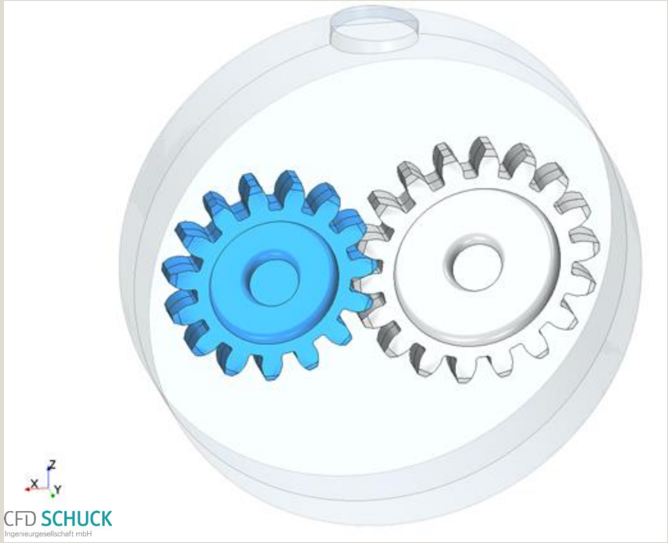


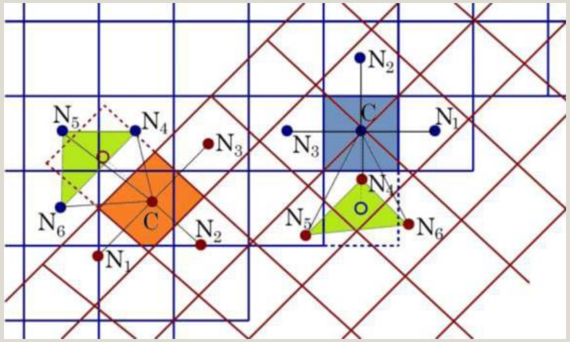


- Gear geometry from www.grabcad.com
- Gear_18: d=200mm, l=50mm, n_T=18
- Gear_15: d=170mm, l=50mm, n_T=15
- Gap modelling by shrinking of the gears (3%)

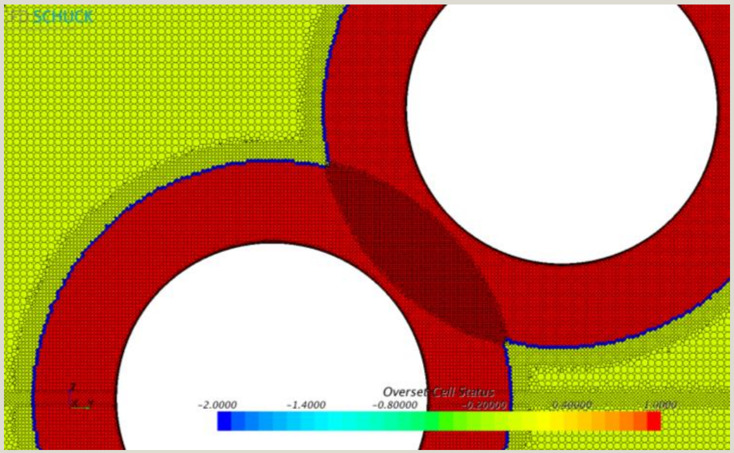
3. MODELLING SETUP AND MESH

- **Multiphase Fluid Flow**
  - Volume of Fluid (VOF) approach
    - Oil sump
- **Rigid Body Motion**
  - Overlapping Overset (Chimera) Method
- **Gear Contact**
  - Zero Gap Overset Mesh Interface
- **Polyhedral Mesh (half model)**
  - ≈ 7.0 mio. cells

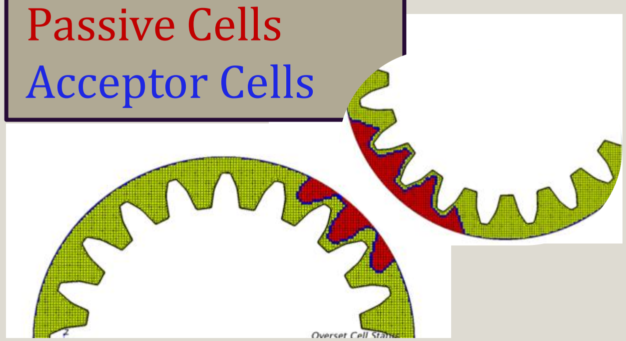




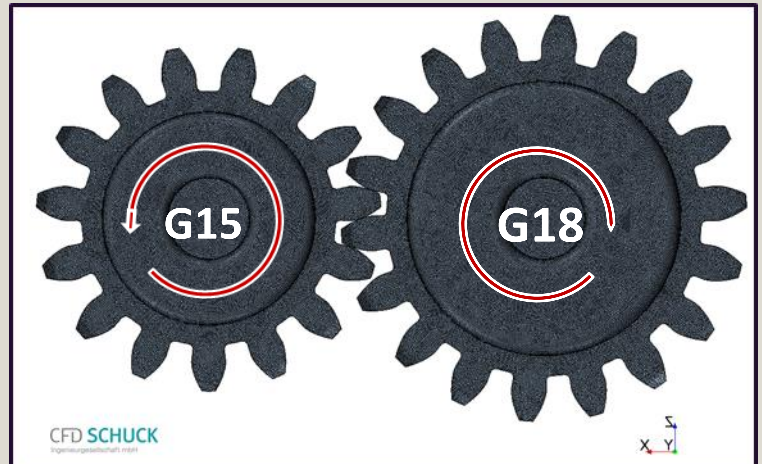
3.4. OVERSET MESH – CELL STATUS



Active Cells
Passive Cells
Acceptor Cells



Gear contact



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3.5. MODEL SETUP

1. Material data:

- Phase 1: Oil ($C_{12}H_{26}$, ISO VG 220, 100° C)
    - density 841.2 kg/m^3
    - dyn. viscosity 0.0149 Pa-s
- Phase 2: Air (ideal gas)

2) Solver Settings (STAR-CCM+® Vers.10.04)

- k-ω-sst-turbulence model
- Total number of rotations 2

→ Simulation time requirements:
≈ 14h per revolution (80CPU)
(≈ 8h per revolution (160CPU))

3) Operation conditions:

- Gear_18 ≈ 850 rpm
- Gear_15 = 1000 rpm

4.1. OIL FLOW

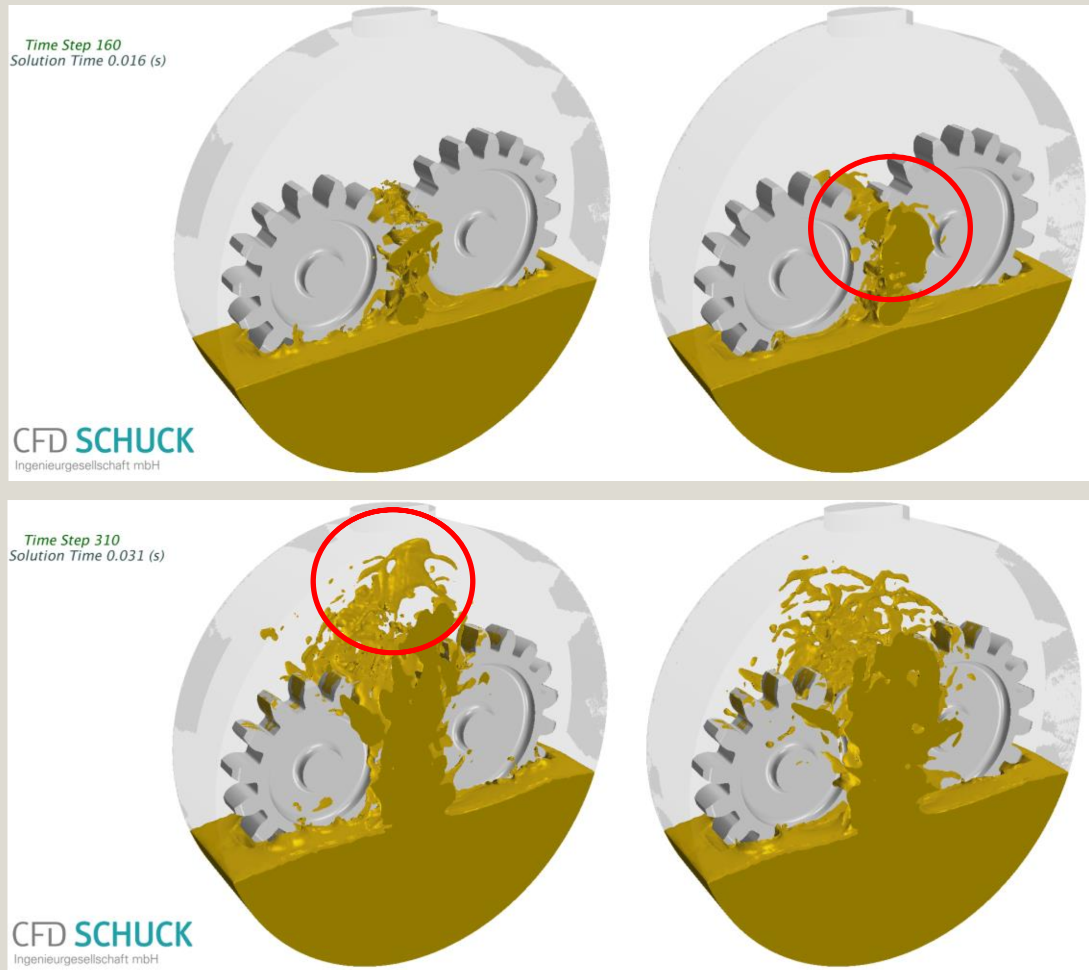
with gap

- stronger distribution of oil flow towards outlet

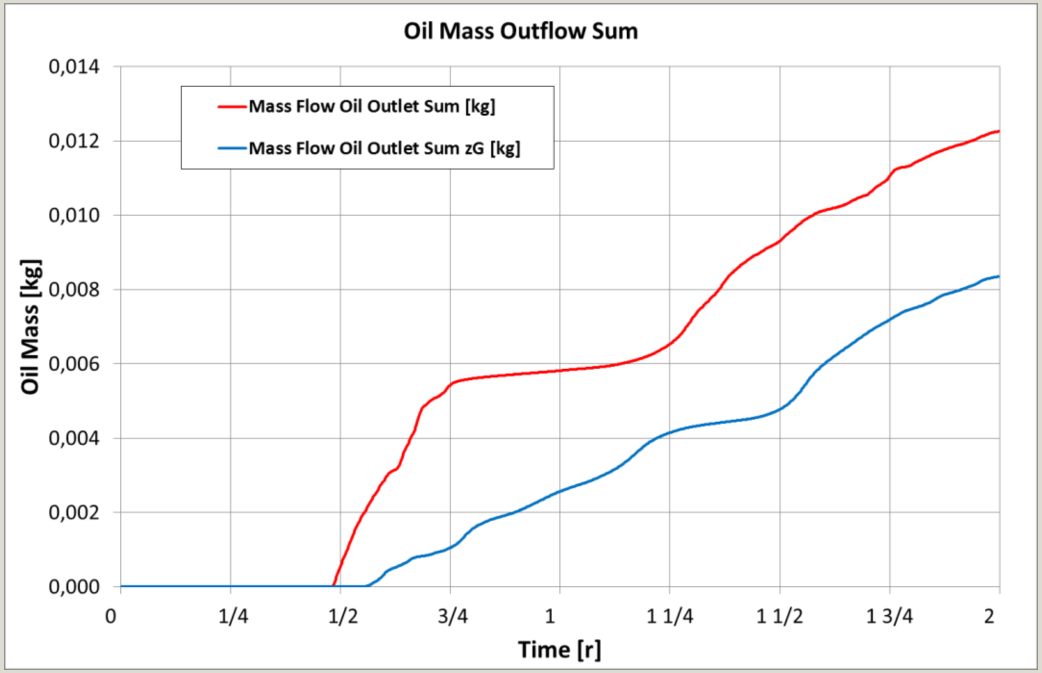
zero gap model:

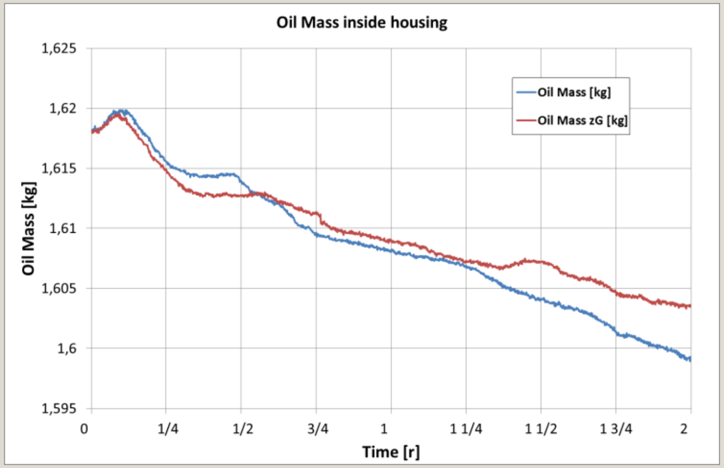
- more oil flow towards side walls of housing

with gap | zero gap model



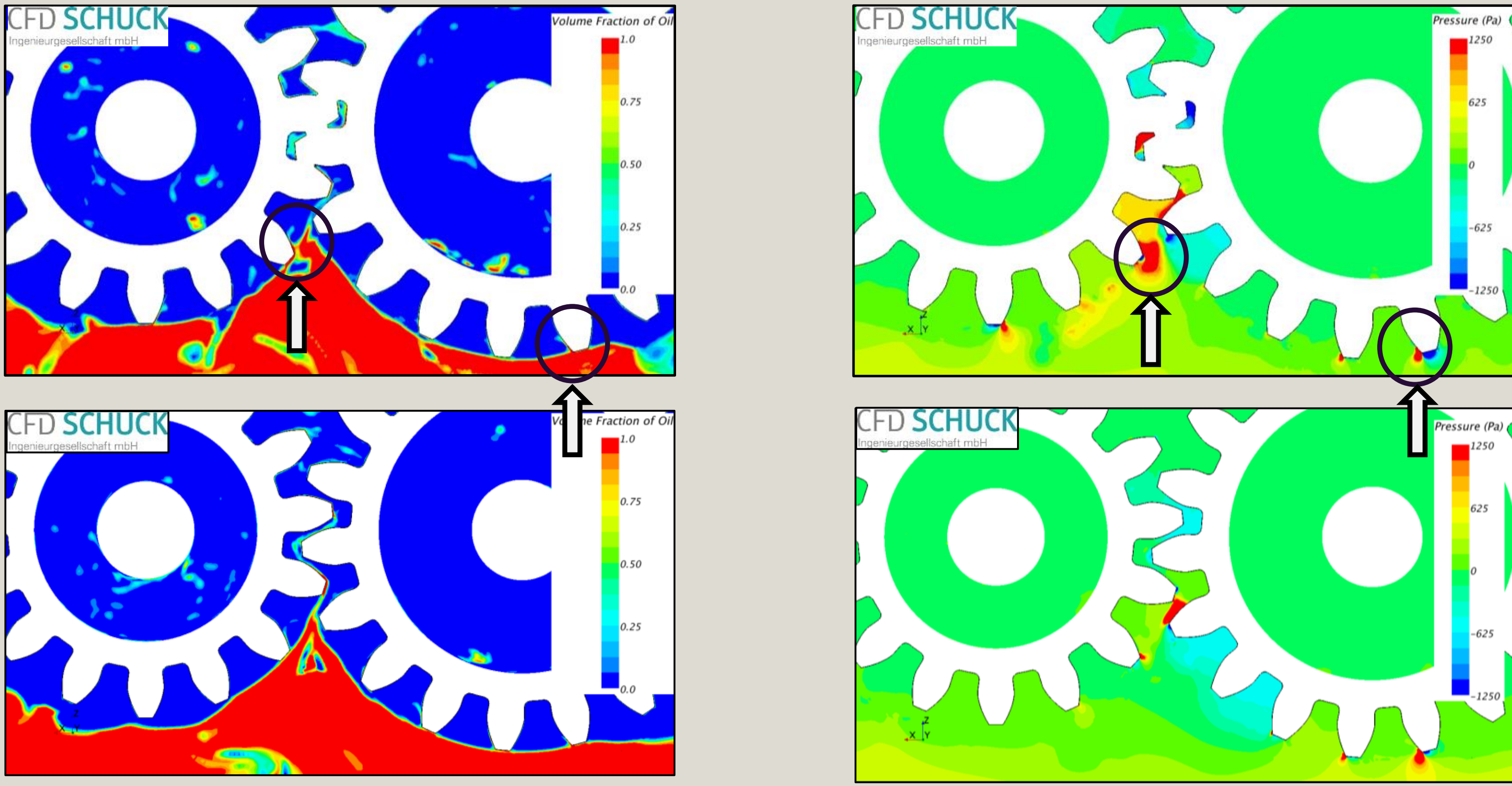
4.1. OIL FLOW





➡ oil mass flow at outlet (with gap model) significantly higher compared to zero gap model after 2 revolutions

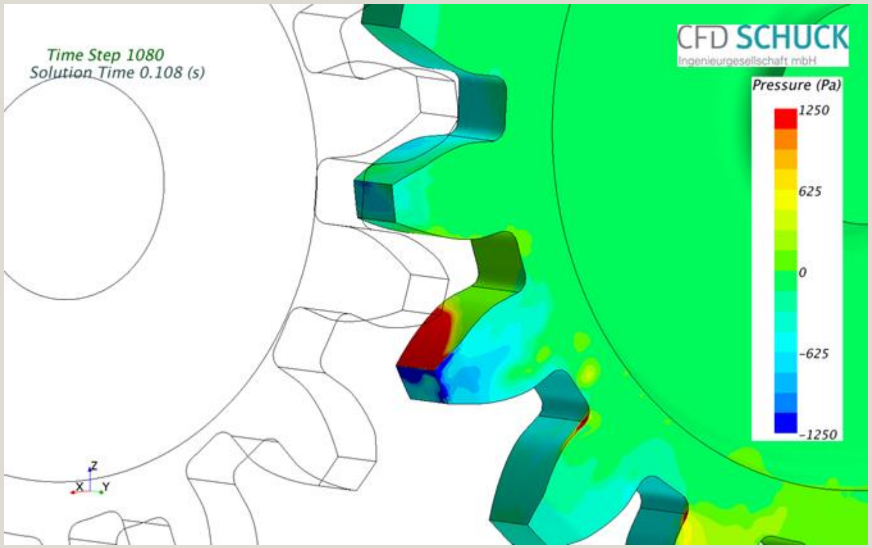
4.2 VOF / PRESSURE DISTRIBUTION (1.5 ROTATIONS)

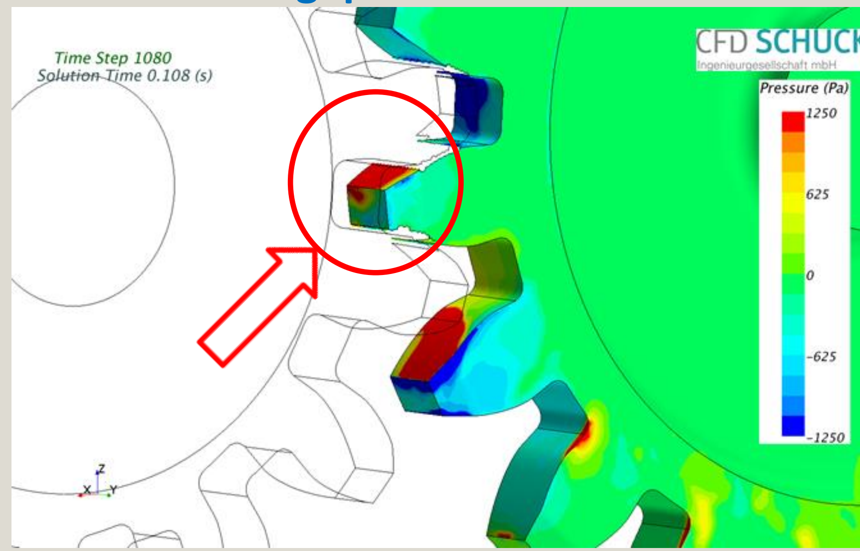


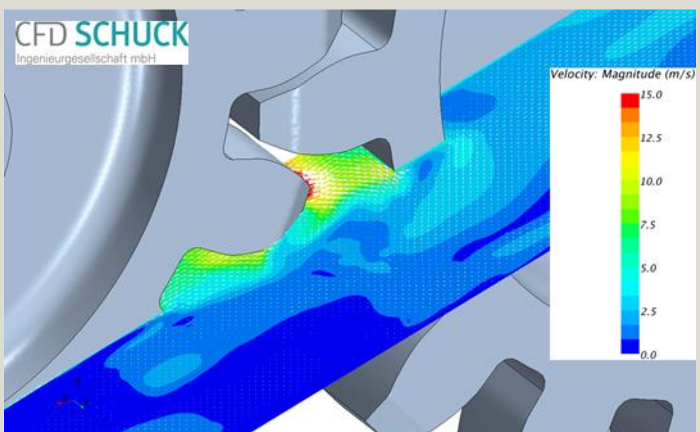
- Oil shearing at tooth tips => Pressure Peaks
- Zero gap model shows high-pressure-zones between teeth contact regions

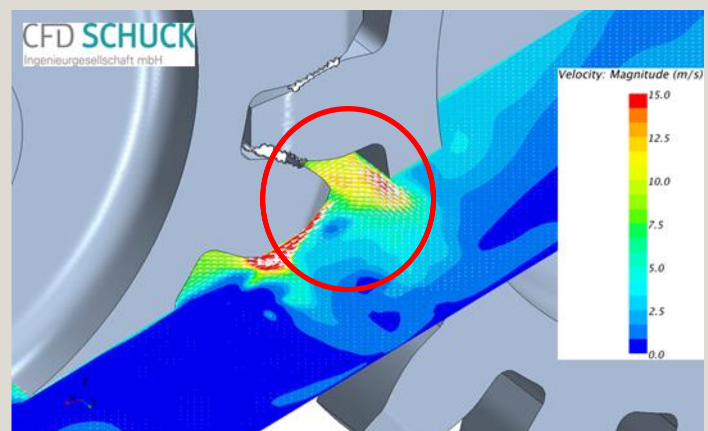
4.2 FLOW DETAILS IN THE GAP REGION

with gap | **zero gap model**









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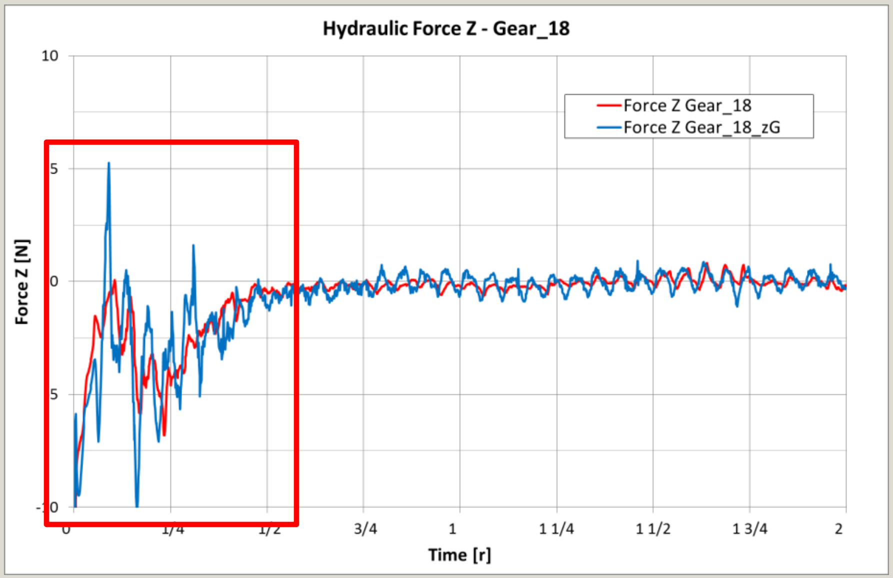
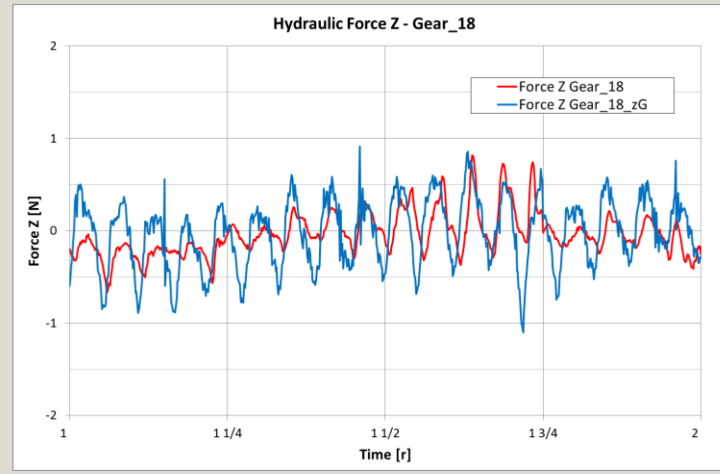
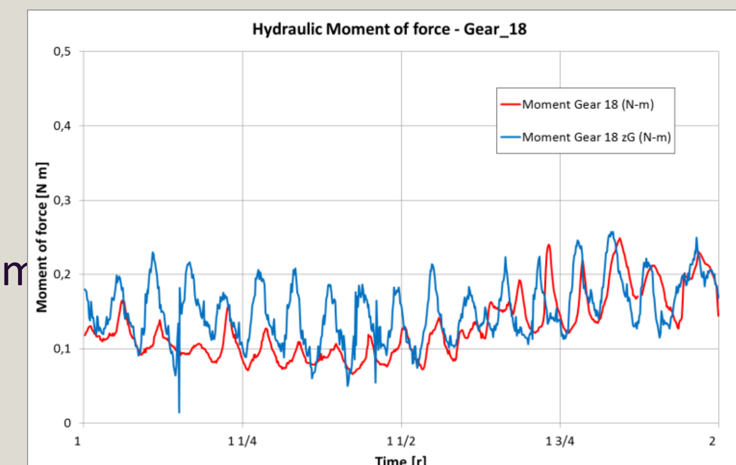
4.2. HYDRAULIC FORCES Z AND MOMENTS







- Similar curves of Forces (and Moments)
- Higher amplitudes in case of zero gap
- Strong oscillation up to 0.5 rotation <= oil displacem

5. CONCLUSIONS AND OUTLOOK

1) Investigation of different types of gap modelling methods for spur gear systems
2) Contact modelling using zero gap interface provides higher accuracy of prediction of oil flow in the system
   - Shows difference in direction of oil transport

     => Increase in Oil outflow (current geometry)
   - Higher hydraulic forces on the gear flanks
   - Difference in the amplitude for the hydraulic forces and moment
3) Zero gap modelling better suited when investigating oil transport in gear systems
4) Further work on the zero gap model with fluid film model is planned after its availability in STAR-CCM+®