# Wear Simulation of Rings & Packings

*How to model wear*

Andreas Kaufmann

4A-Technologie Tage 26.2.2016

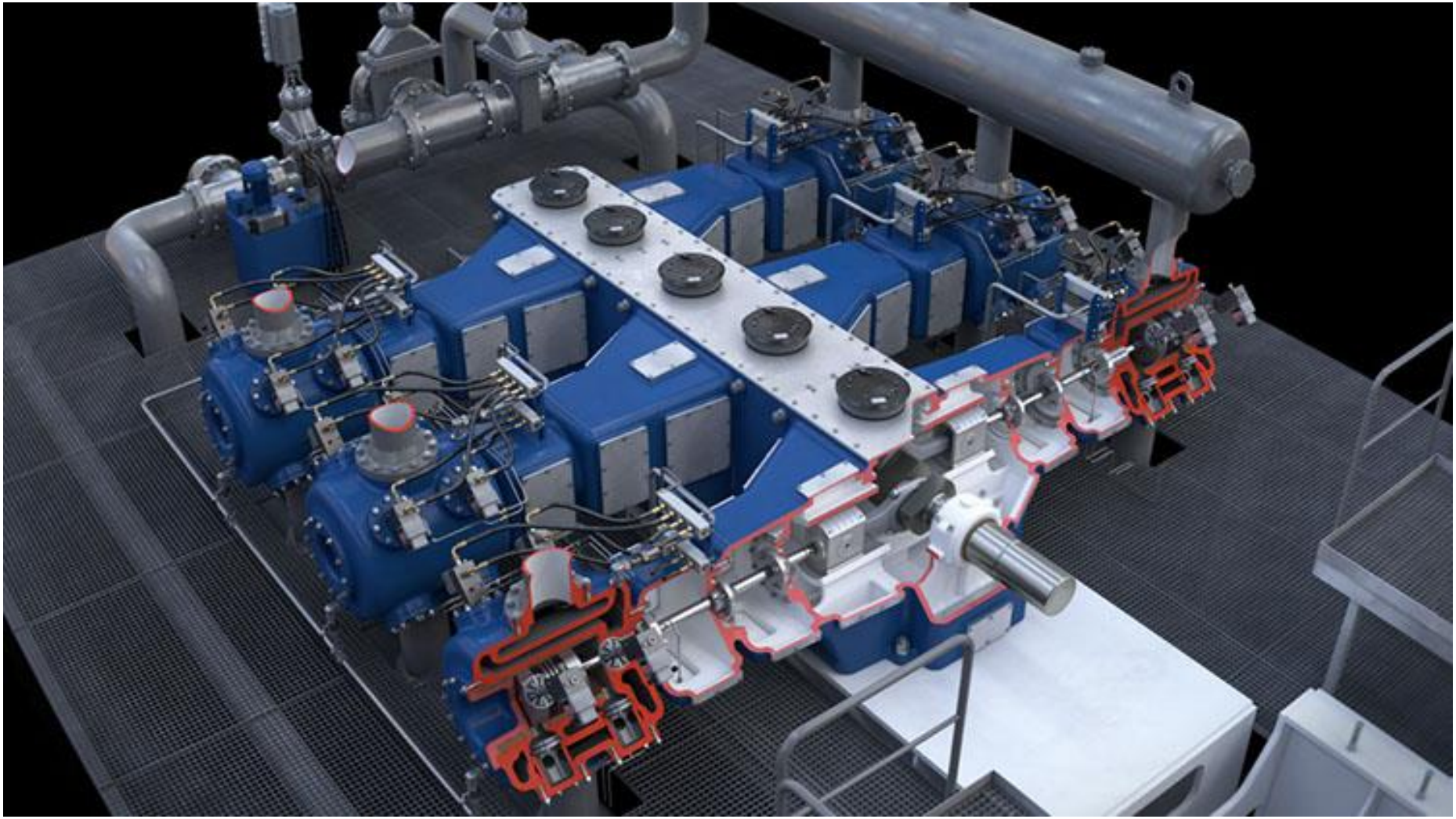
HOERBIGER

# Introduction - HOERBIGER

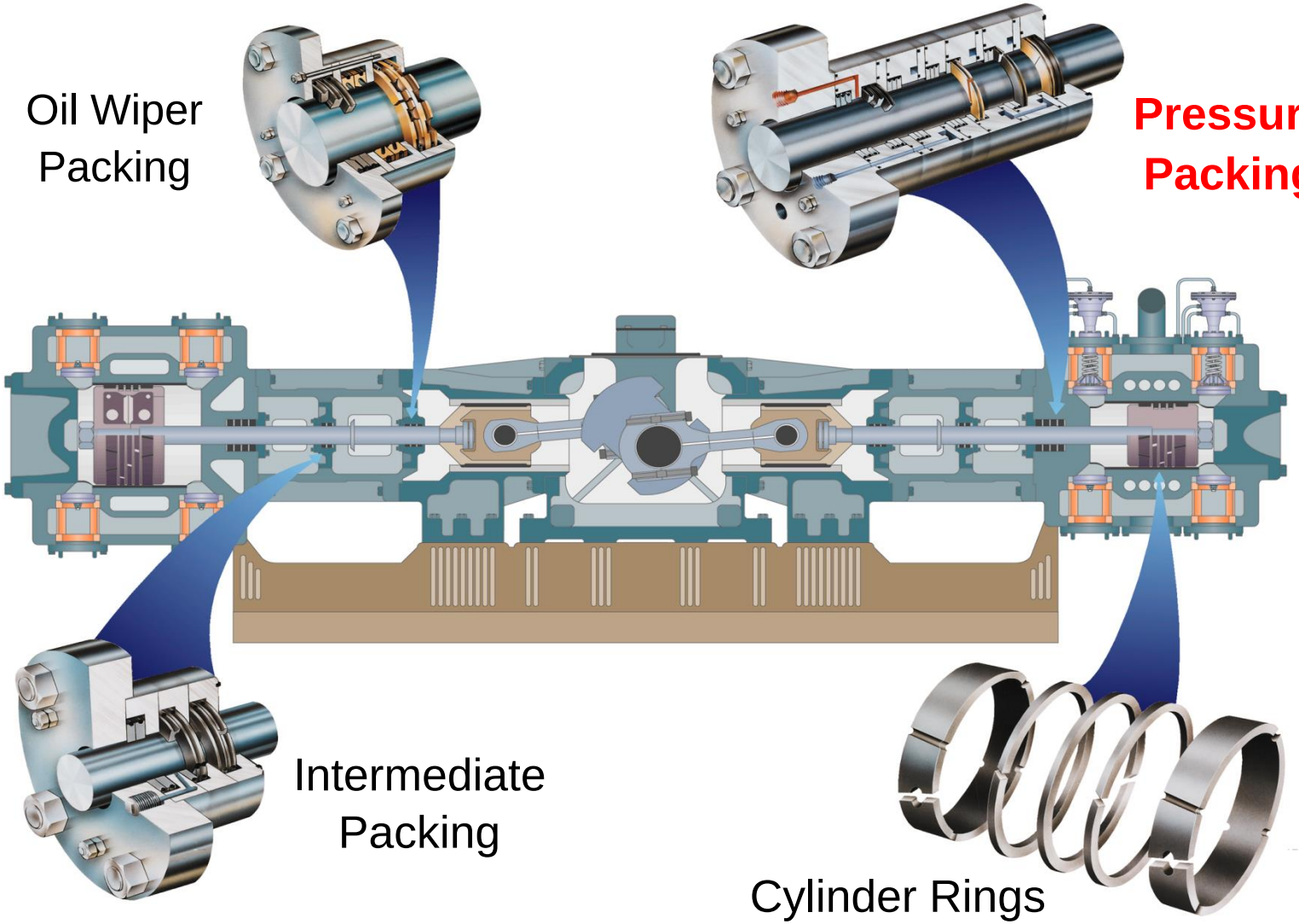
- worldwide leading company
- 130 Production & Service Locations
- 7000 Employees
- ~ 1.000 Million EUR revenue
- Founder: Hanns Hörbiger

- Compressor Solutions
  - Compressor Valves
  - Rings & Packings
  - Mechatronics

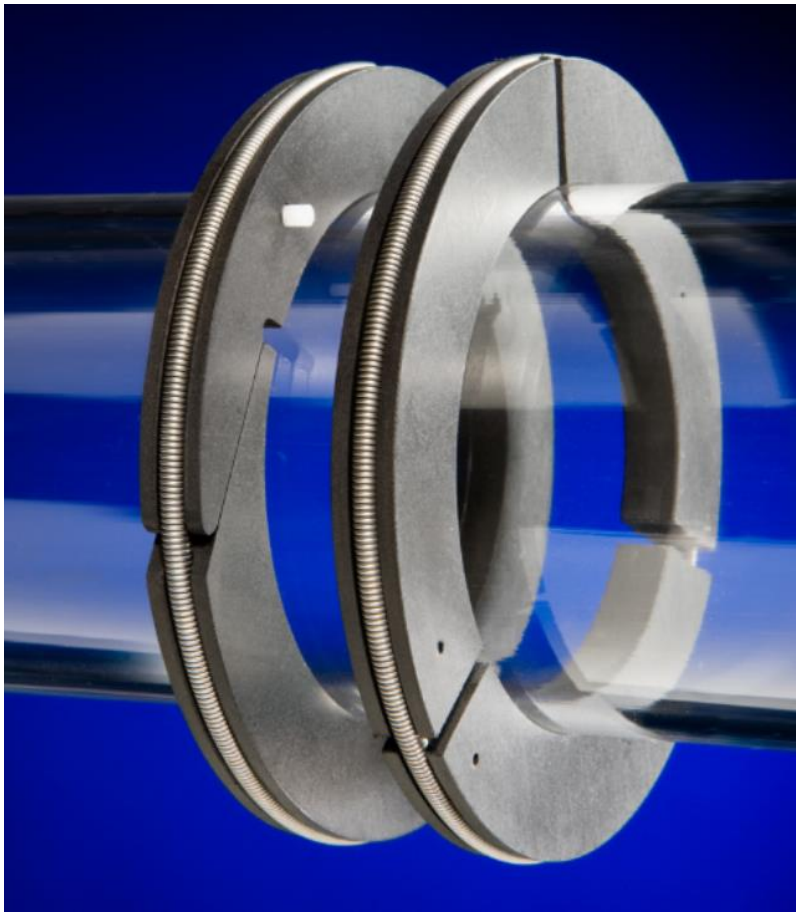
# Reciprocating Compressor



# Rings & Packings



# Different Types of Rings & Packings



Radial Tangent Ring Pair

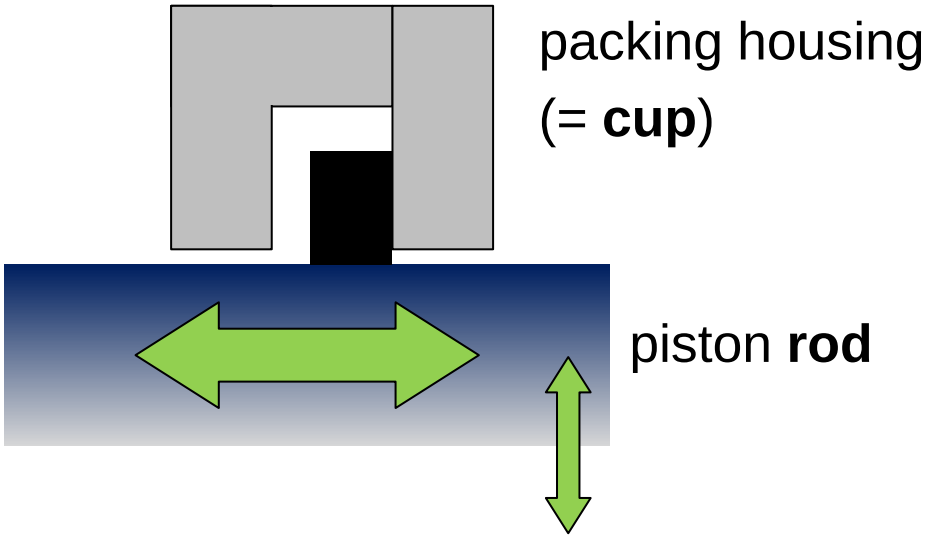
BCD

# Dynamic Seals

- Rings and Packings are dynamic seals. Requirement is to seal a gap between moving and stationary components in crank gear machines:
  - piston compressors
  - piston pumps
  - combustion engines
  - steam engines

- Packings

  seal gaps between packing housing and piston rod



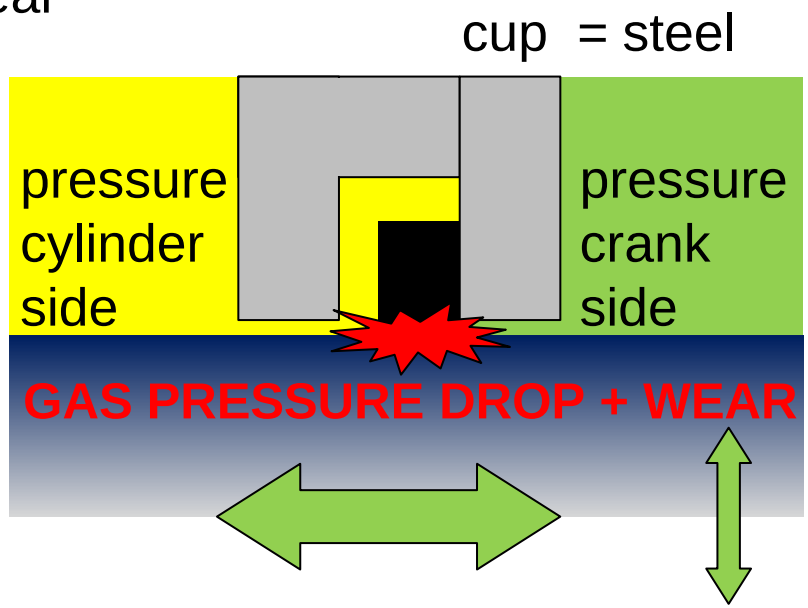
# Boundary Conditions

| | | |
|---|---|---|
| Gas: | air, $H_2$, $N_2$, $O_2$, process gases, natural gas, … | |
| Ring Material: | typically PTFE based (+ glass fibers, carbon, … ) | |
| Temperature: | rod: | 60 - 250°C dependent on application (flash temperatures higher) |
| | cup: | possibility to be cooled |
| | ring: | dependent on location |
| Service time: | 1 year | |

$p_{cylinder} > p_{crank}$

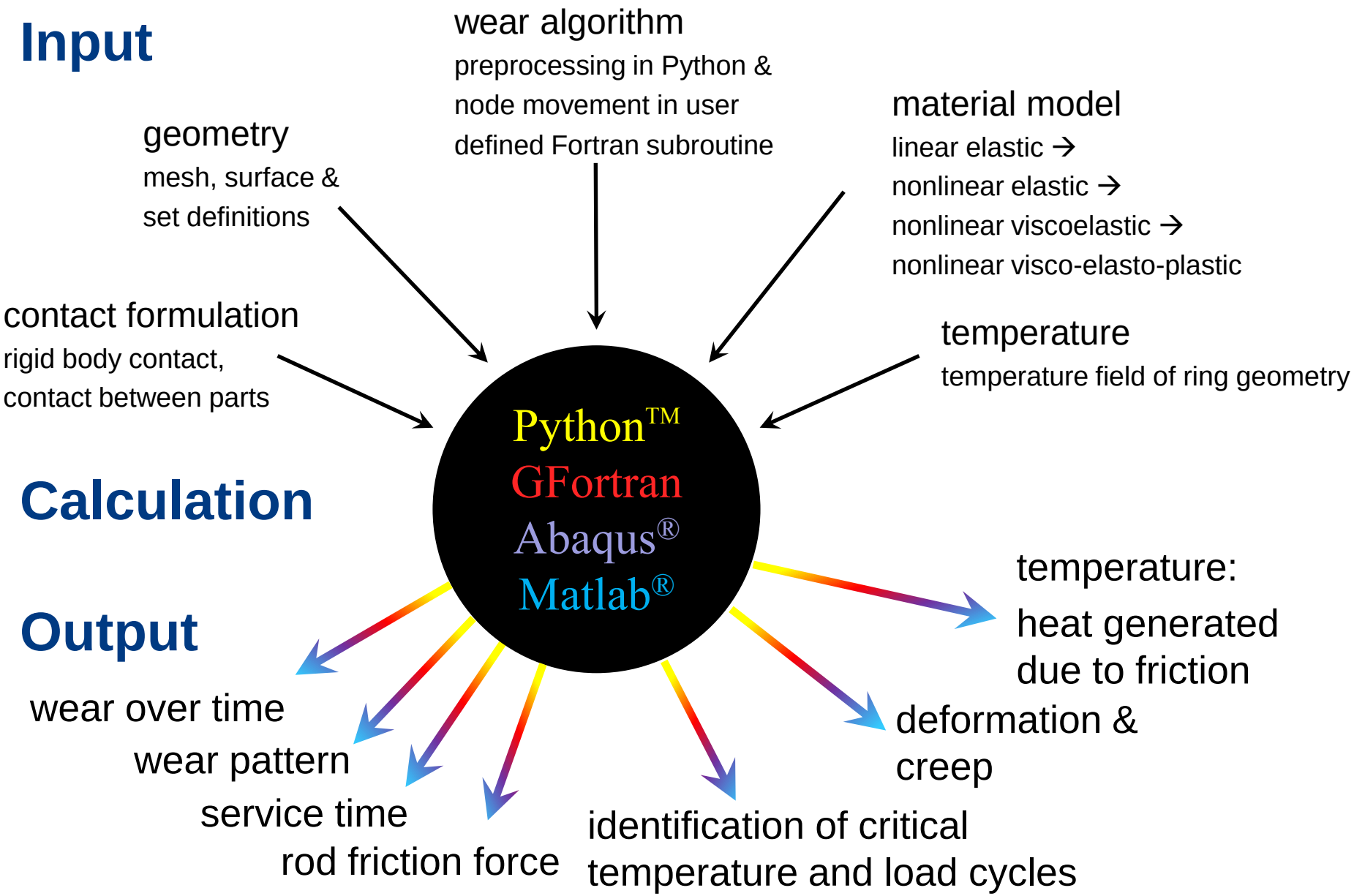
gas pressure governed by

$$\nabla^2 p(x,y) = 0$$




| | |
|---|---|
| rod: | steel (+ coating) |
| | 1700 – 372 rpm |
| stroke | 89 – 300 mm |

# SIMULATION OF WEAR


Input
wear algorithm
preprocessing in Python &
node movement in user
defined Fortran subroutine
geometry
mesh, surface &
set definitions
material model
linear elastic →
nonlinear elastic →
nonlinear viscoelastic →
nonlinear visco-elasto-plastic
contact formulation
rigid body contact,
contact between parts
temperature
temperature field of ring geometry
Calculation
Python™
GFortran
Abaqus®
Matlab®
Output
temperature:
heat generated
due to friction
wear over time
wear pattern
service time
rod friction force
deformation &
creep
identification of critical
temperature and load cycles

# Model Restrictions

| | | | |
|---|---|---|---|
| time scales: | a) compressor running with | > 5 Hz | wear |
| | b) service time of the rings | 1 year | creep |

the smaller time scale is not considered directly:

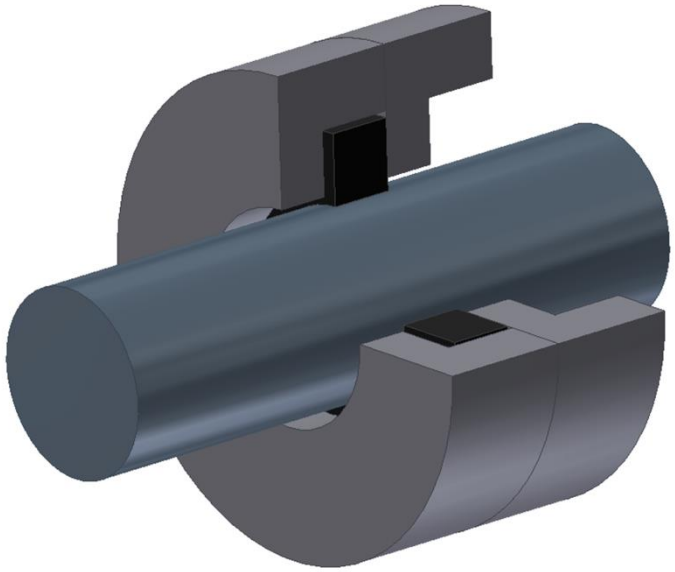
➔ wear is averaged over time as wear/time

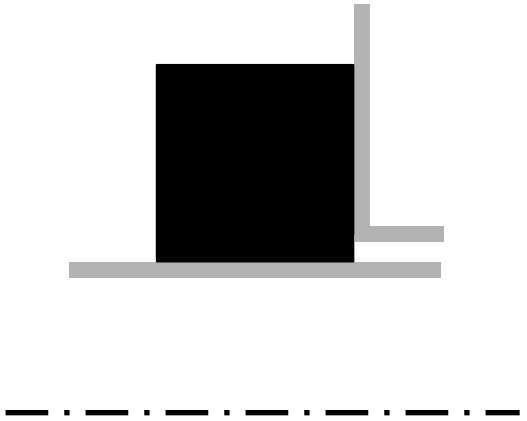
➔ no consideration of the reciprocating motion (slip-stick)

➔ for the 1st approach all relative motion is considered frictionless

→ the coefficient of friction can be used as a fit parameter

→ reduction of calculation time





2D:

# DEVELOPMENT OF A LINEAR ELASTIC WEAR MODEL FOR AN AXISYMMETRIC SOLID RING

# Wear in Abaqus via UMeshMotion

User definded subroutines used:

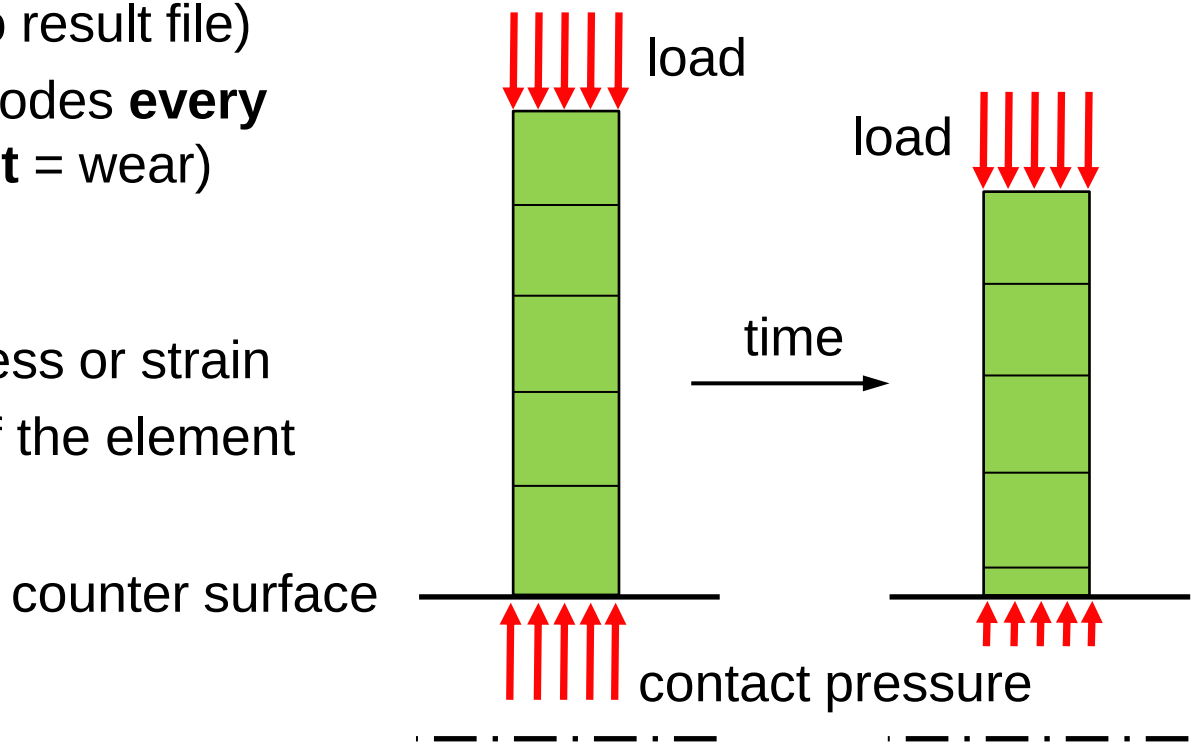
URDFIL (access to result file)

UMeshMotion (moving nodes **every increment** = wear)

moving nodes:

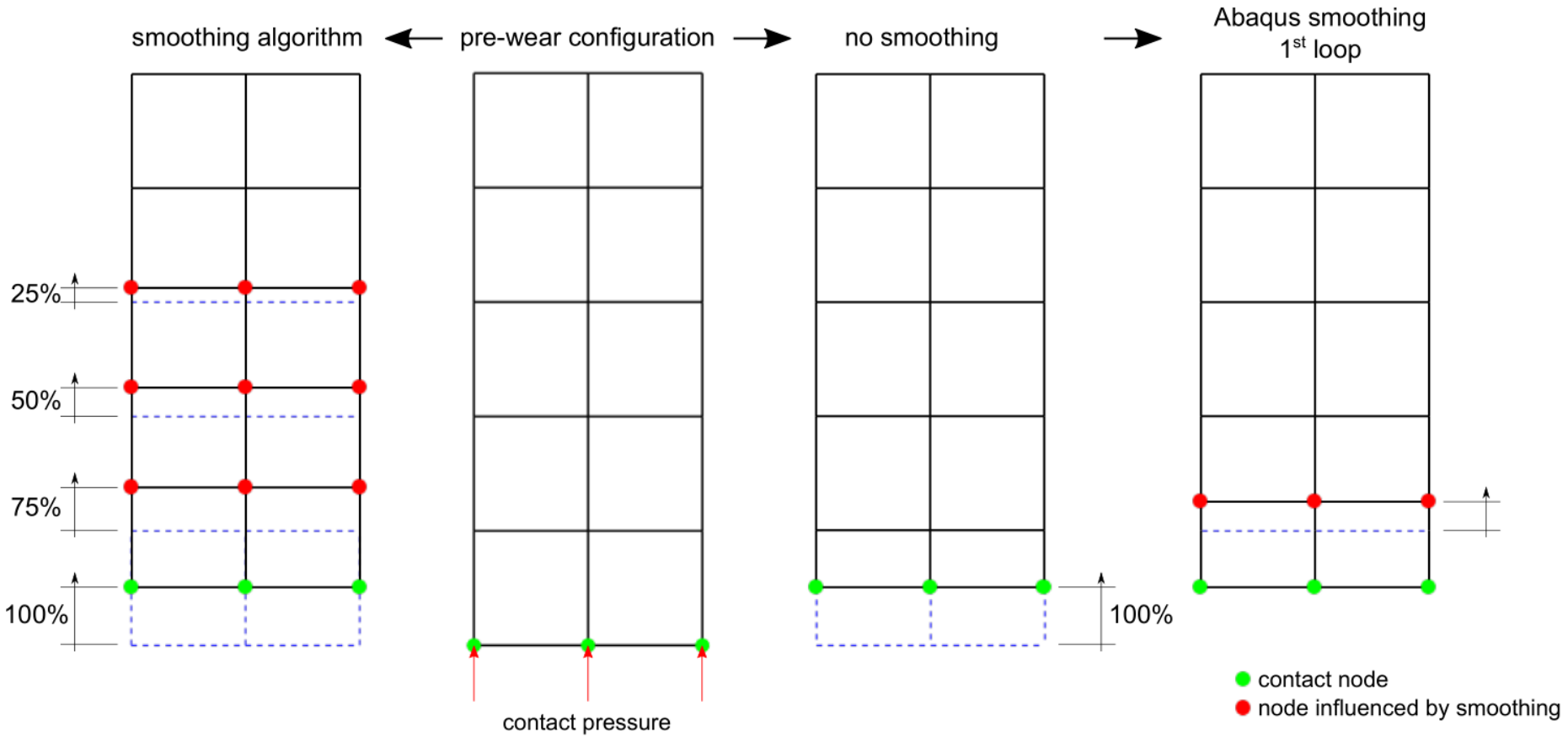
➔ causes **NO** stress or strain

➔ reduces size of the element



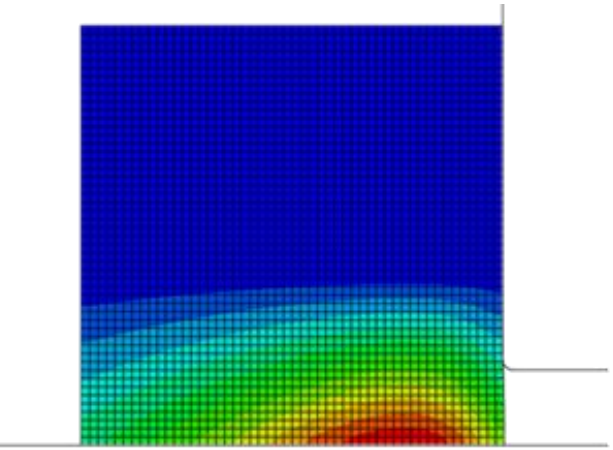

**wear** = proportional to **contact pressure** and **time increment**

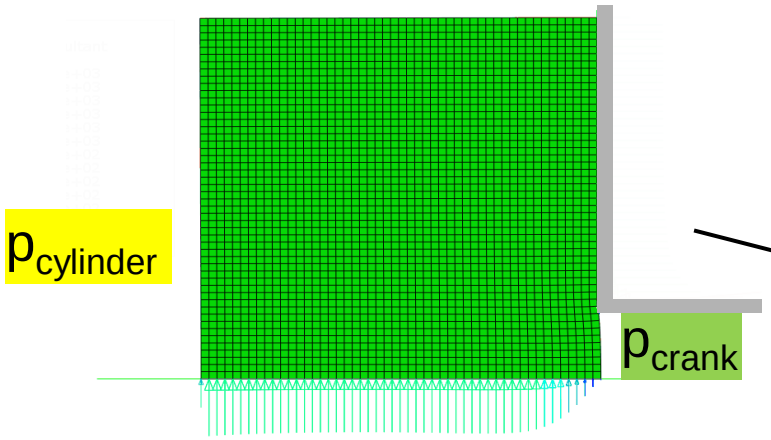
# Neighbor node ‘trick’ ➔ higher total wear



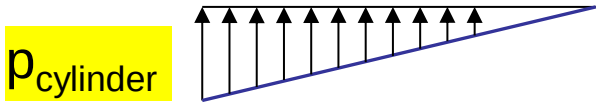
# Abaqus Implementation
# 2D Model

result of wear calculation:
**wear distribution after a few wear cycles**

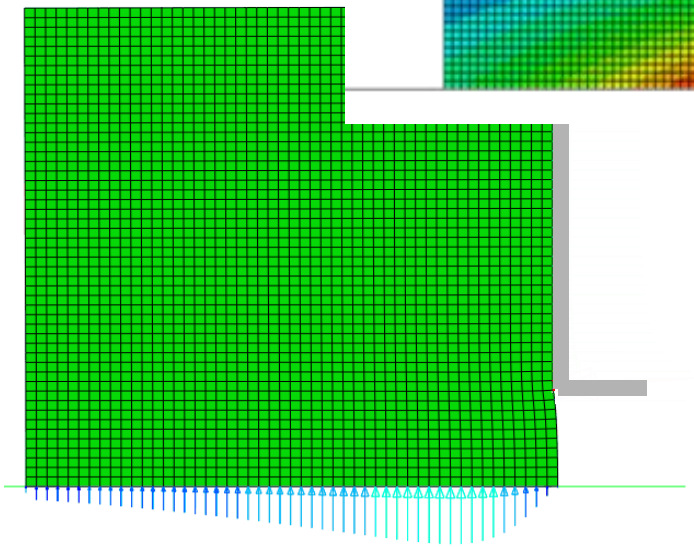





**wear model**




**calculated gas pressure distribution**



**contact pressure distribution for the wear calculation**

# Scheme of Coupled Analysis

call of a single Python file, which then calls

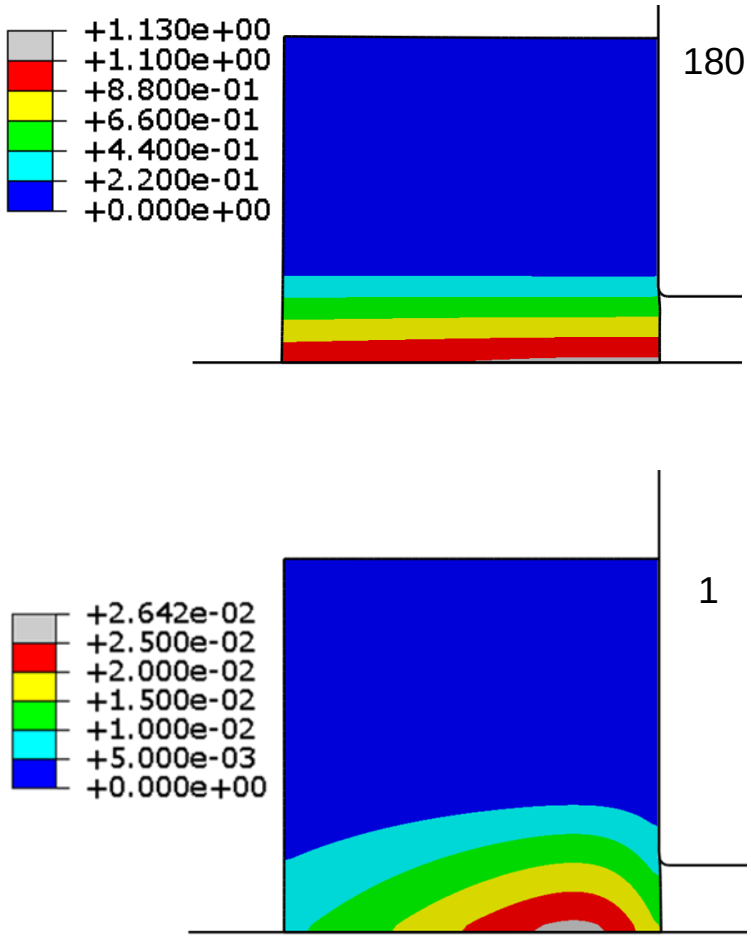
| | | |
|---|---|---|
| 1. | initialization: input file main (wear) model | Abaqus |
| 2. | getting parameters for loops | Python |
| 3. | finding radial neighbor nodes of the contact nodes | Python |
| 4. | generation of input file for sub model | Python |
| 5. | calculation of sub model (gas press. distribution) | Abaqus |
| 6. | generation of input file for main model | Python |
| 7. | calculation of main model (wear) | Abaqus, Fortran |
| 8. | last calculation unload main model | Abaqus |

repeat n times

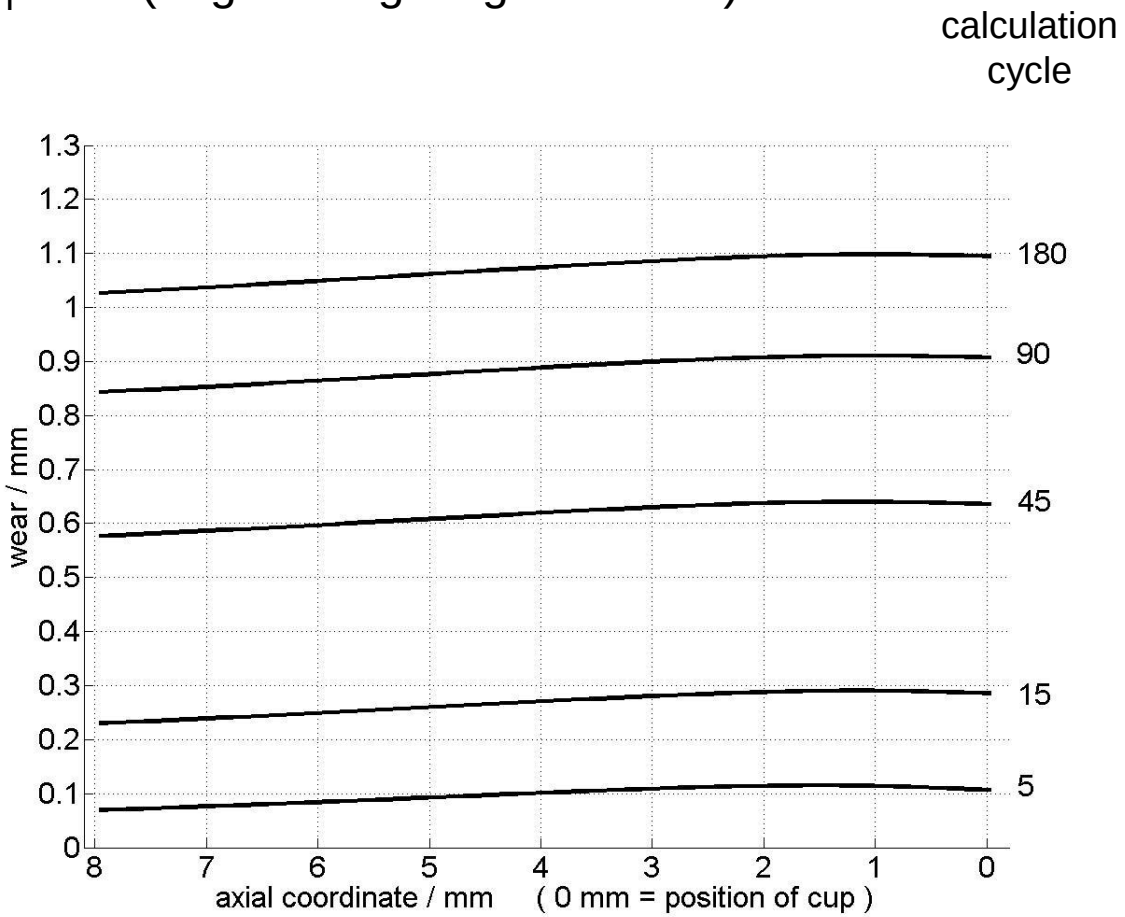
| | | |
|---|---|---|
| 9. | post processing | Python, Matlab |

# 2D – Results

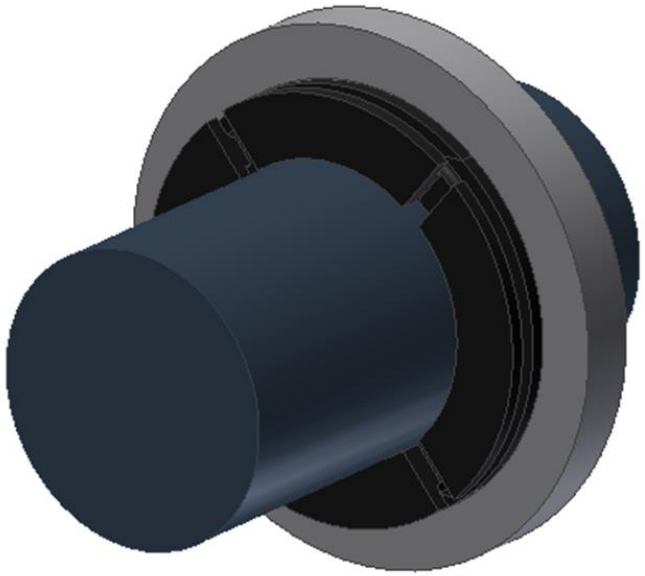
node movement
= wear in mm

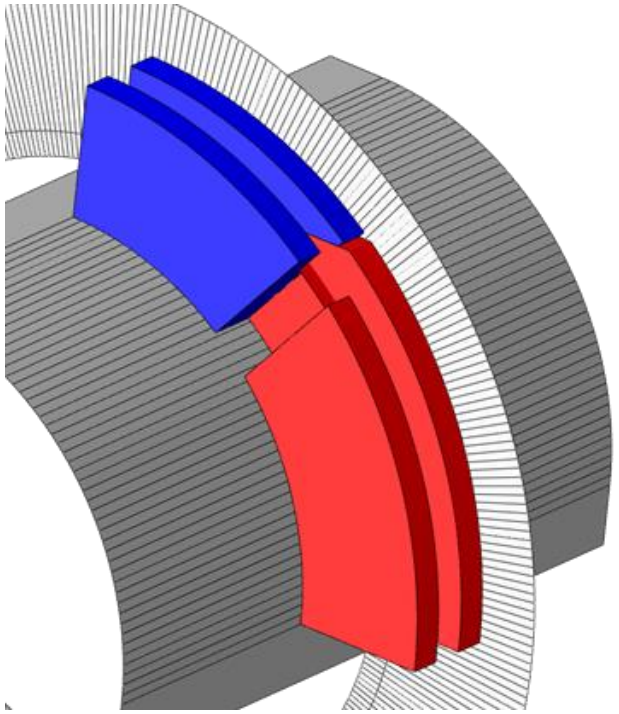



distance rod – unloaded ring after wear
(original ring height = 8 mm)



# 3D:

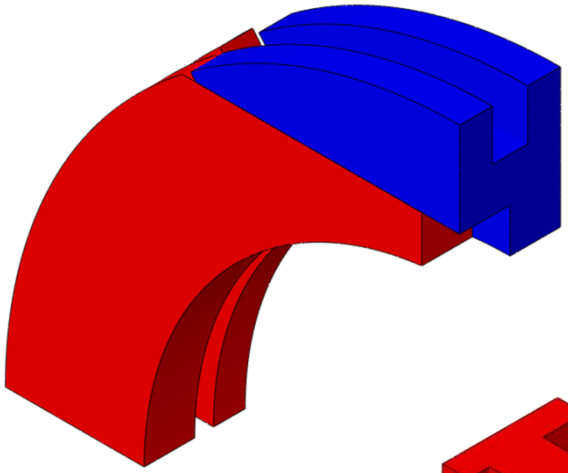




# REAL GEOMETRY SIMULATIONS

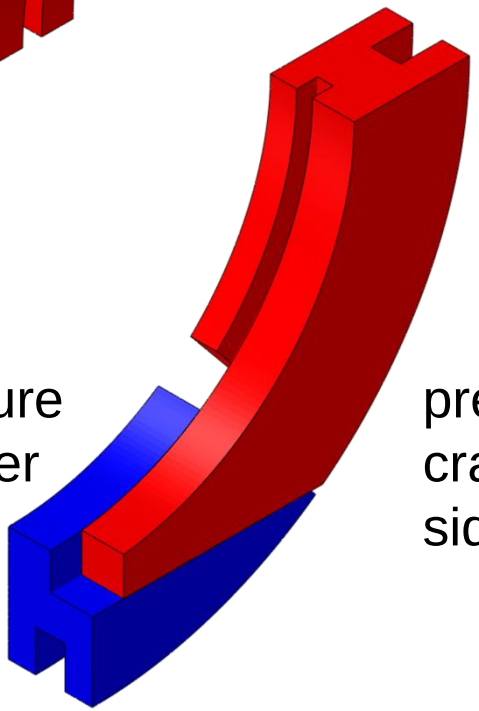
# BCD RINGS

# 3D BCD Ring Geometries



rod size:
50 mm

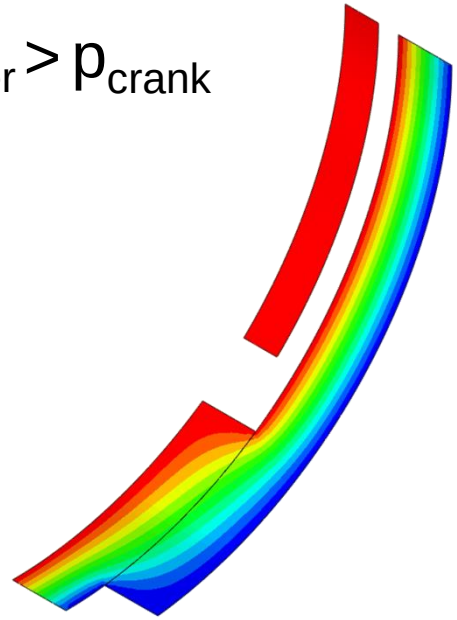
2D pressure distribution model:
area of ring-rod contact



pressure cylinder side

pressure crank side

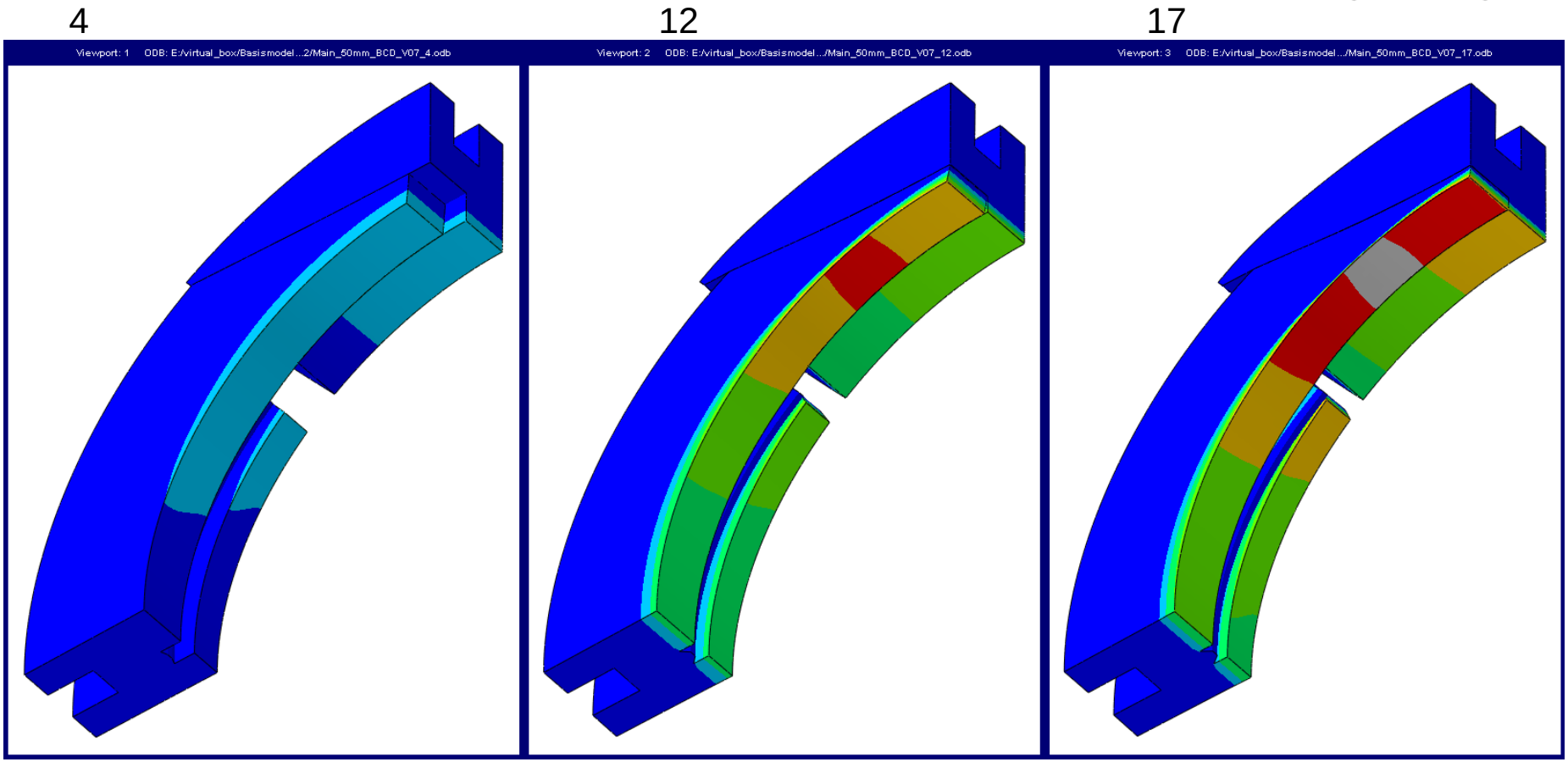
$p_{cylinder} > p_{crank}$



# Evolution of Wear

rod Ø 50 mm, linear elastic

Calculation cycle:

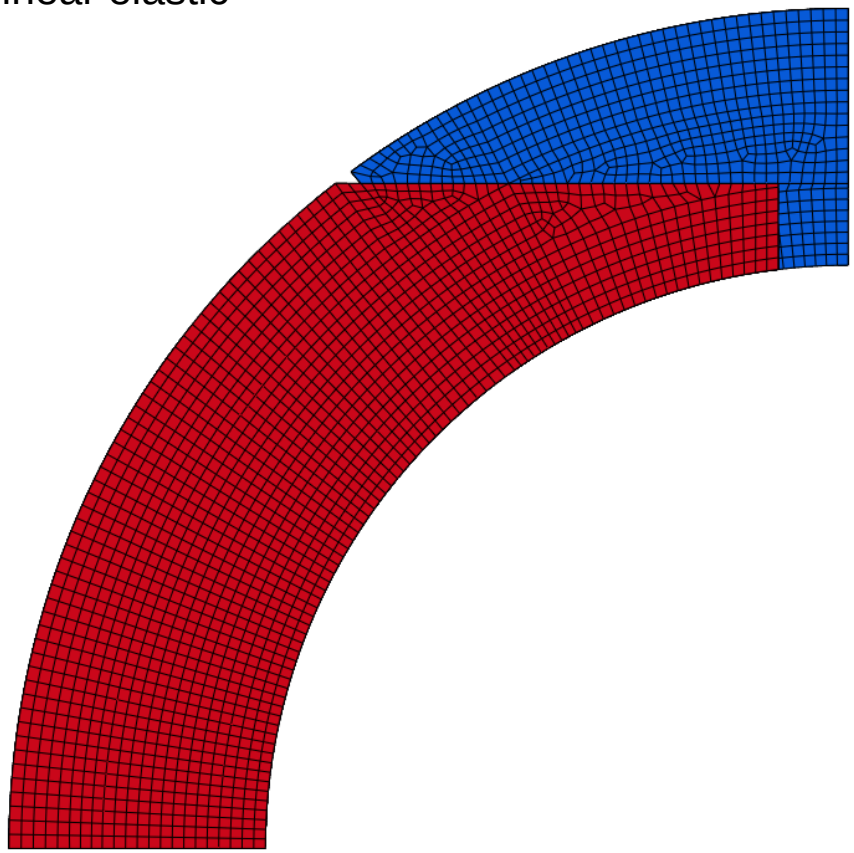


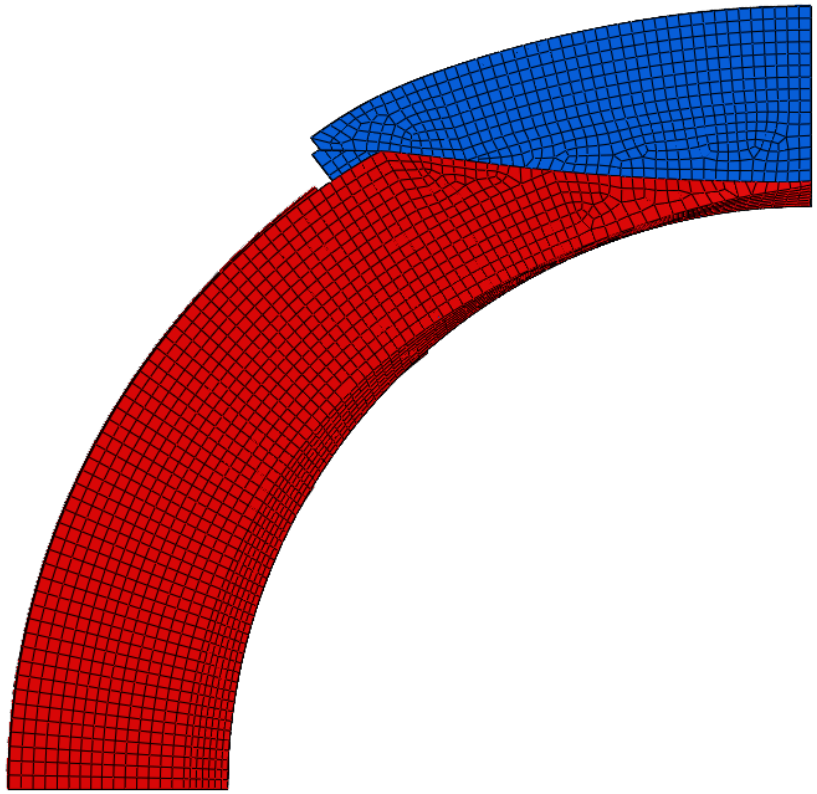
# Status quo: Worn BCD Ring

rod Ø 50 mm

max. wear 3 mm

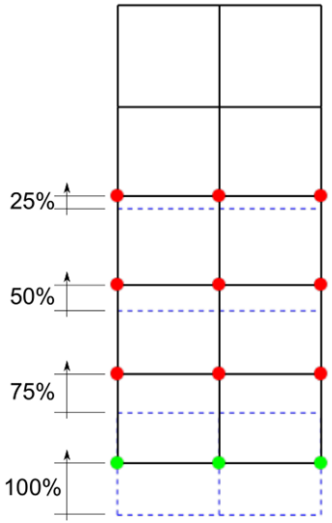
linear elastic

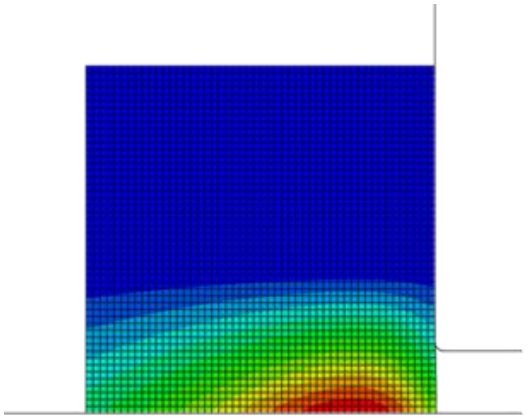




# Summary & Outlook

implementation of wear:

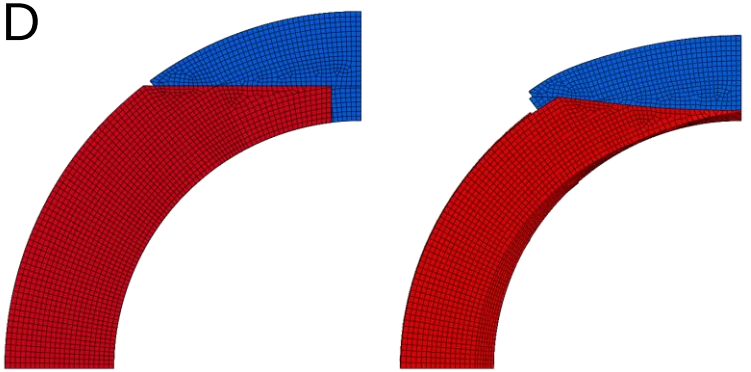


Python +
Abaqus +
Fortran user defined Subroutines
(stress free movement of nodes makes wear possible)

➔ wear can be calculated → wear pattern & wear over time

successful implementation of wear in 2D and 3D
using a linear elastic material model



**Outlook**:
implementation of a complex material model