FEDERAL MOGUL

18. Aachener Kolloquium

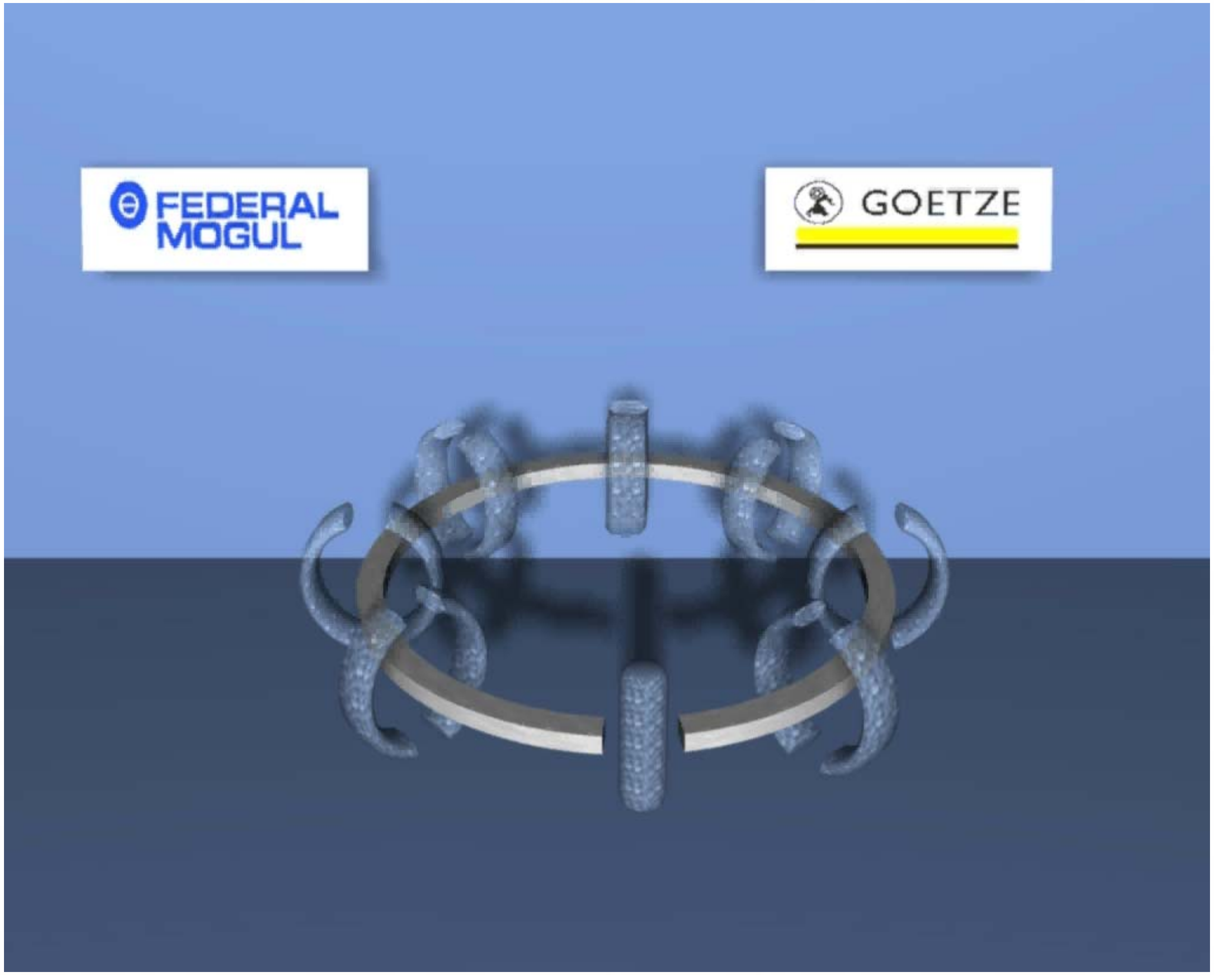
Fahrzeug und Motorentechnik 2009

Optimization of

piston ring dynamics

by direct 3D analysis

of dynamic effects



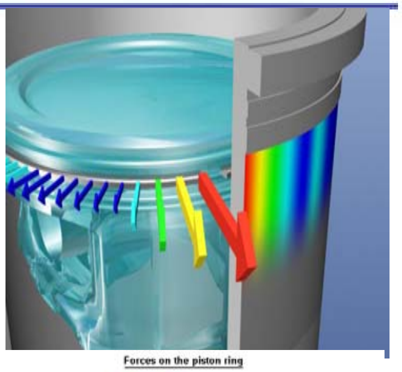
Agenda

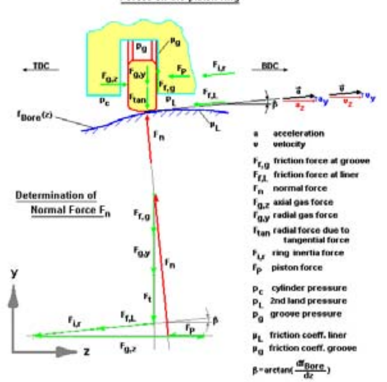
- Fundamentals 3D Ring Pack
  - 3D Hydrodynamic
  - 3D Gas flow
  - 3D Ring-Forces
- Example of optimization of blow-by and ring movement

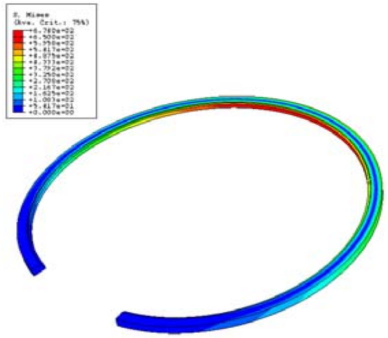
3D Ring Pack Dynamics

FUNDAMENTALS OF 3D Ring Pack

- 3D dynamic twist calculation
- 3D dynamic movement calculation
- 3D gas-flow calculation
- 3D hydrodynamic friction
- 3D Influence of heat transfer on radial pressure
- 3D Radial hydro-dynamic pressure distribution between Ring and Liner

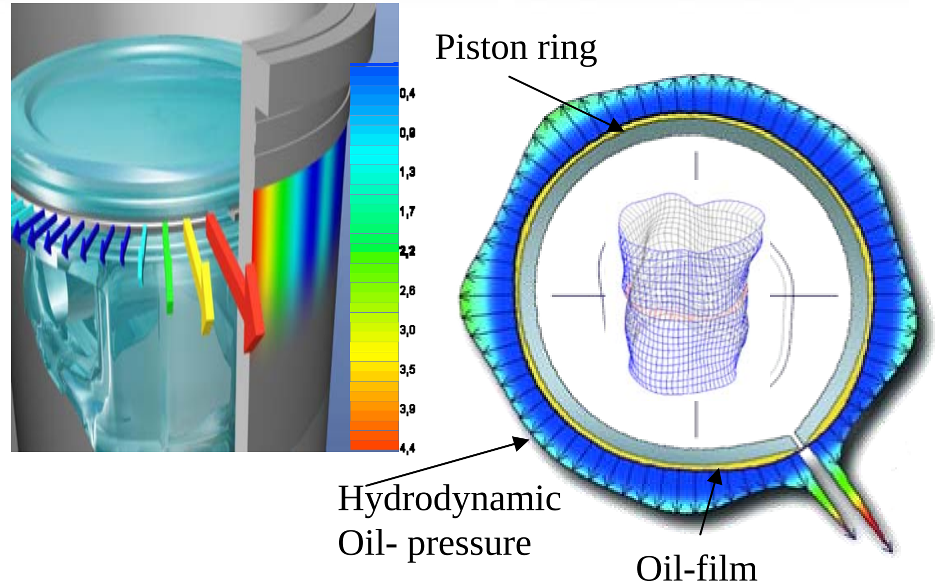




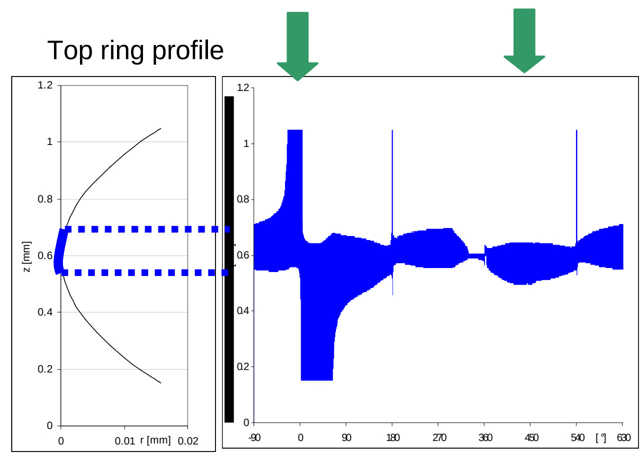


Fundamentals of FM-3D Ring Pack calculation

- 3D Influence of heat transfer on piston ring radial pressure distribution
- 3D Radial hydro-dynamic pressure distribution between Ring and Liner
- 3D hydrodynamic friction



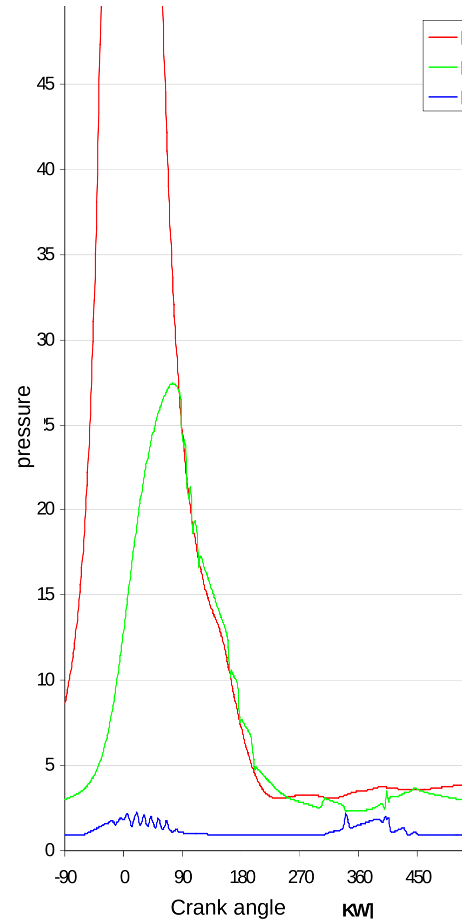
Physical factors:
- Bore distortion on every axial level through the liner
- K-Factor of ring
- Piston ring pressure distribution
- Ring peripheral surface
- Engine crank kinematics

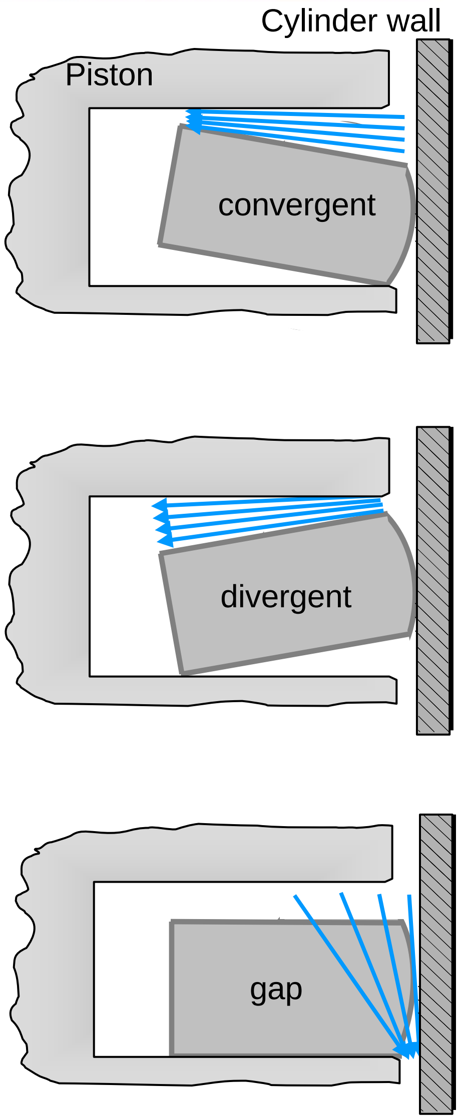


Fundamentals of FM-3D Ring Pack calculation

- 3D gas-flow calculation

• Physical factors:
•Clearance by twist
  • divergent
  • convergent
• In the clearance between the ring and the groove, the sound velocity cannot be exceeded.
•subsonic-flow
• Heat exchange between the groove flanks and the gas flow. Therefore, the flow is neither isothermal nor adiabatic.
• Gas friction
• Gas choke by friction





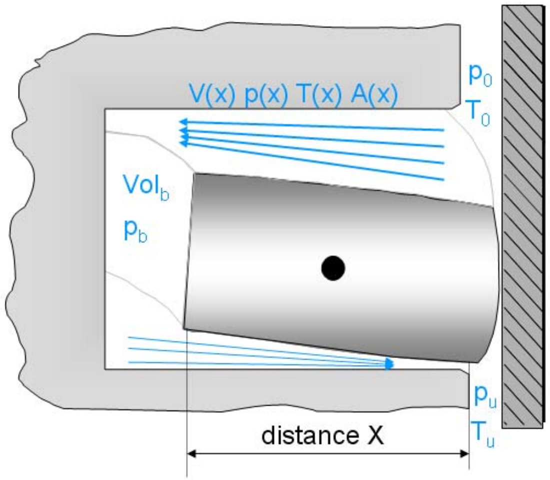
3D Gas Flow Analysis

End of the clearance
V_b Gas speed
P_b Gas pressure
T_b Gas temperature
A_b Gas flow area

Begin of the clearance
V_0 Gas speed
P_0 Gas pressure
T_0 Gas temperature
A_0 Gas flow area

$$M = \frac{V}{c}$$

M Mach Number
V Gas speed
C sound velocity



- **subsonic-flow.**
- **In the clearance between the ring and the groove, the sound velocity cannot be exceeded.**
- **Heat exchange between the groove flanks and the gas flow. Therefore, the flow is neither isothermal nor adiabatic.**

Divergent clearance

M has its maximum close to the start of the clearance

Convergent clearance

M has its maximum at the end of the clearance

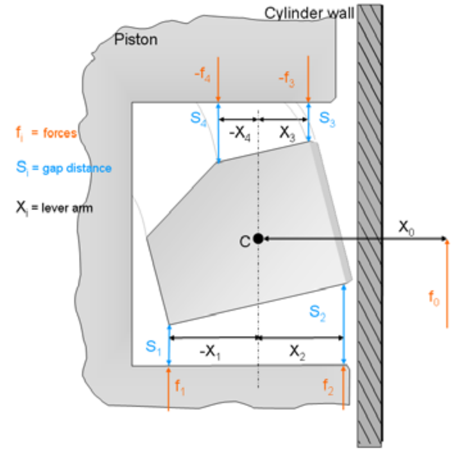
3D Twist and Movement Analysis

The criterion of a rectangular ring for the stability contact on one groove side is:

$$F_{mas} \leq \frac{1}{3} \Delta p\, a \qquad \text{or}$$

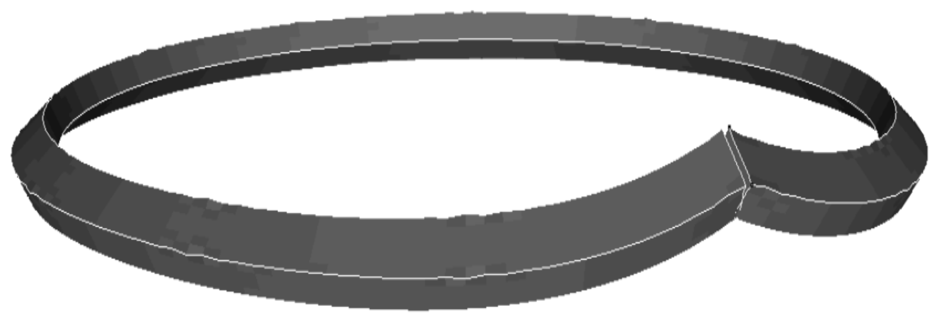
$$F_{mas} \geq \frac{2}{3} \Delta p\, a$$

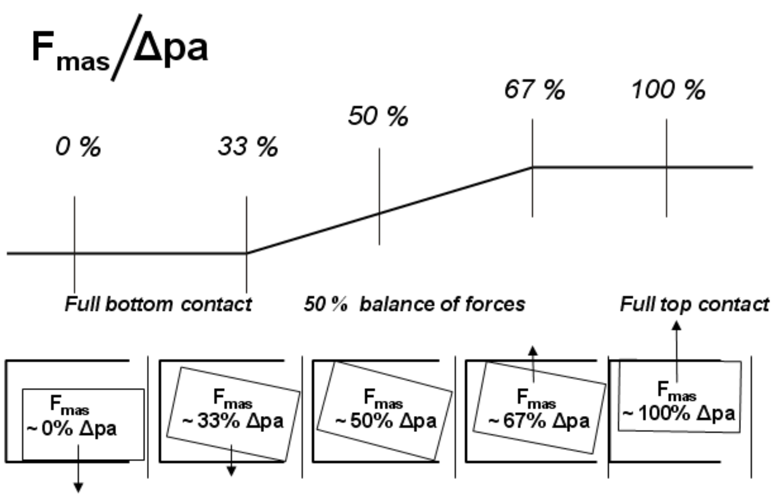
Δp = pressure gradient
a = wall thickness
F_{mas} = Mass force



The simplification describes the condition where a stabilized flank contact is given

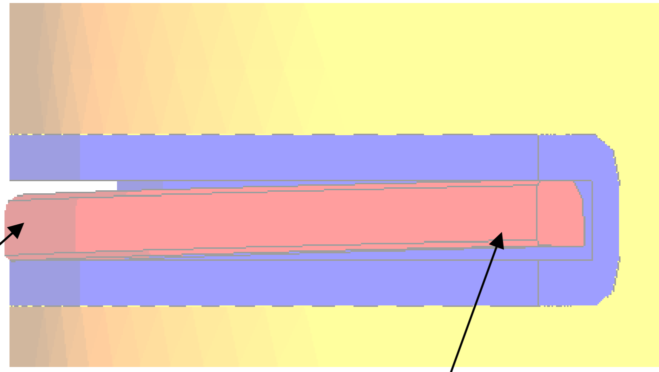
Axial Position of a top ring movement from calculation result





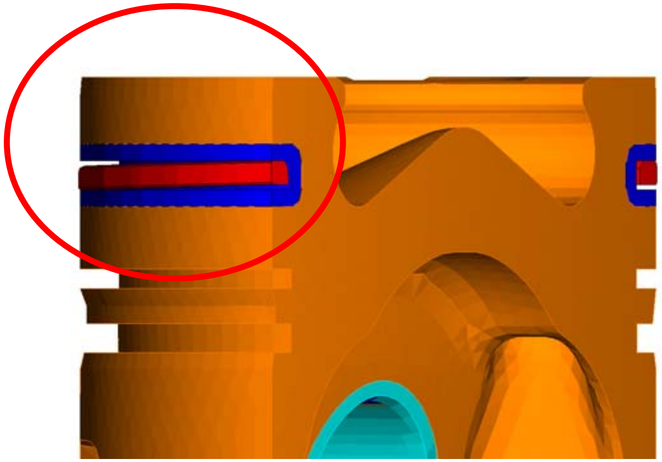
Fundamentals of FM-3D Ring Pack calculation

- 3D dynamic movement calculation
- 3D dynamic twist calculation

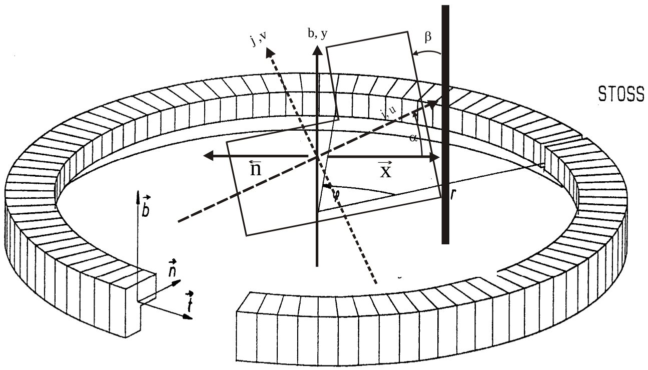


~ 60 °
bottom groove contact

Gap end
top groove contact



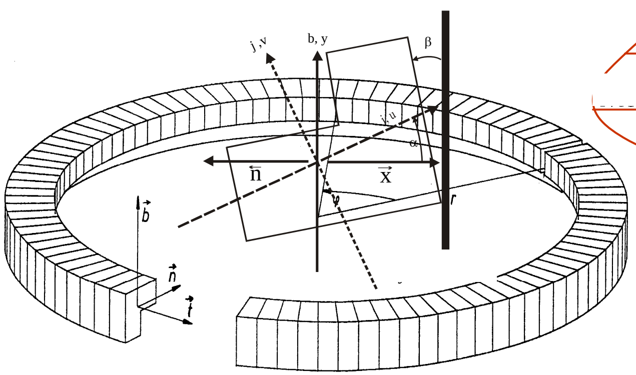
<u>Physical factors:</u>
•The twist and arching of the piston ring is caused by the moments acting on the rings, which can also occur in rectangular rings
•movement as a result of moments and forces
•contact around the circumference on both ring flanks are possible

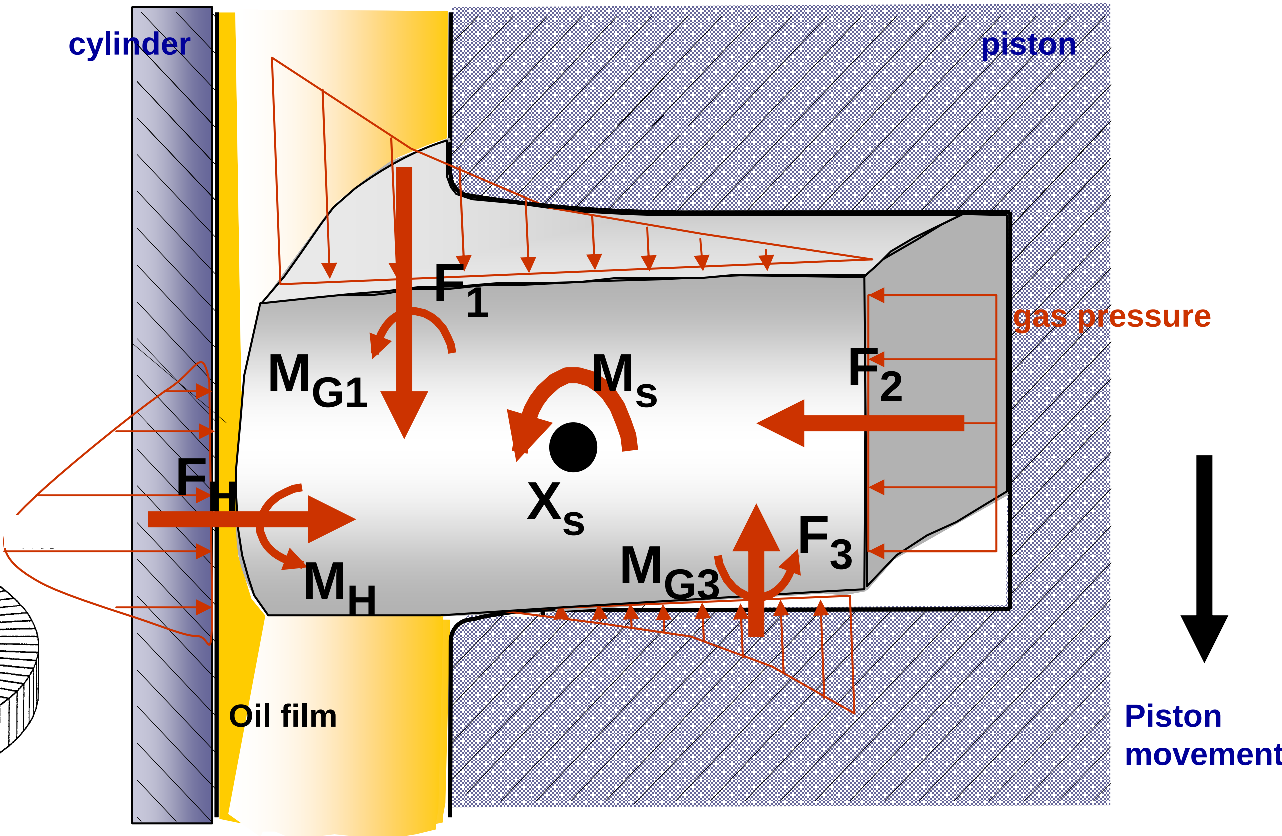


3D Twist and Movement Analysis

Moments and Forces as a result of gas flow, hydrodynamic and piston ring properties.

The twist and arching of the piston ring is caused by the moments acting on the rings, which can also occur in rectangular rings





Example of FM-3D Ring Pack calculation

Model data

2 l 4 cylinder gasoline engine:

P (75kW @ 5600 rpm),

M (130Nm @ 4600 U/min)

Pmax (86bar @ 4000 rpm)

Piston ring data:

top ring: rectangular ring

2nd ring: taper faced ring

Oil ring: 2 piece oil ring

Measurement

Under full load condition, the measurement in the basic version of the engine showed a blow-by result of 42 – 45 l/min.

Simulation

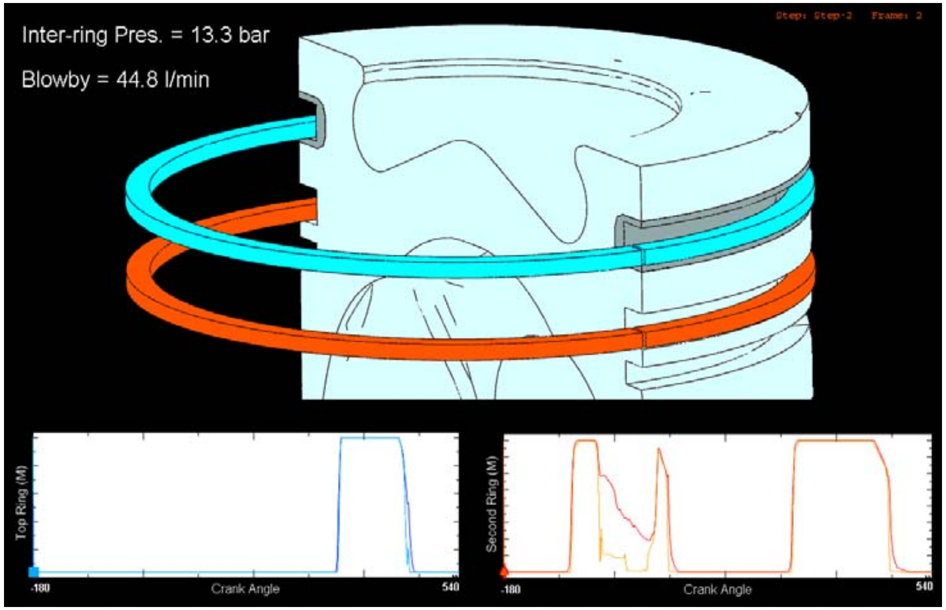
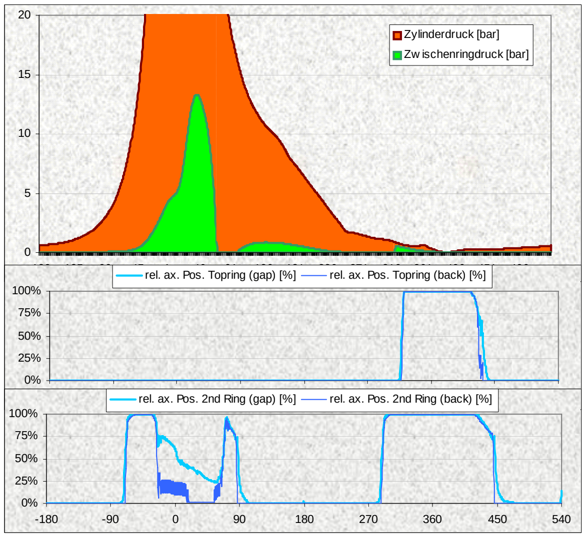
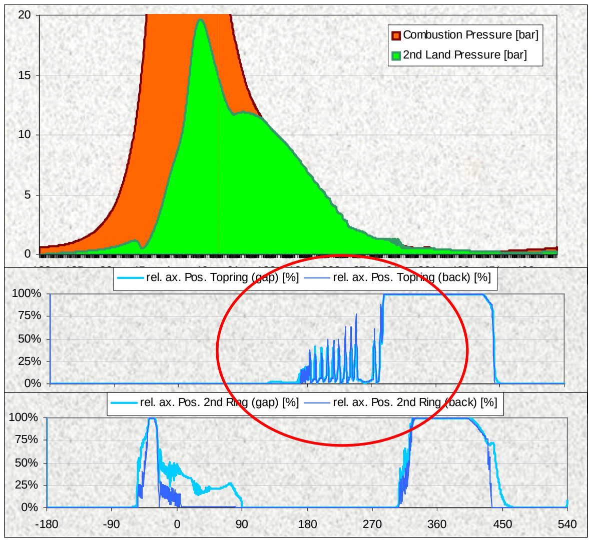
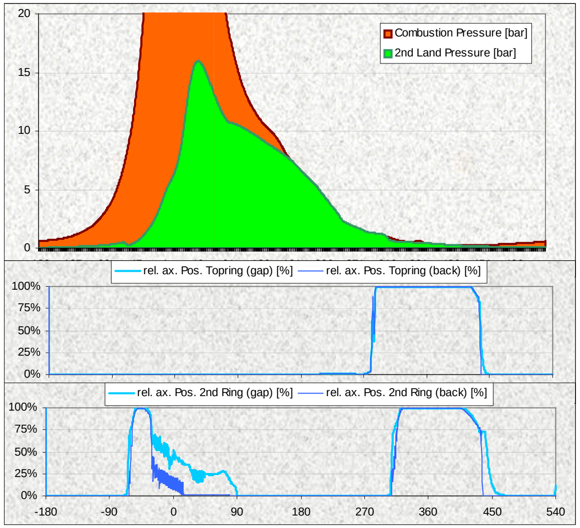


Illustration of pressure conditions and ring movements (gap and ring back)

Blow-By 42 – 45 l/min.	Blow-By 33- 35 l/min.	Blow-By 36 - 38 l/min.







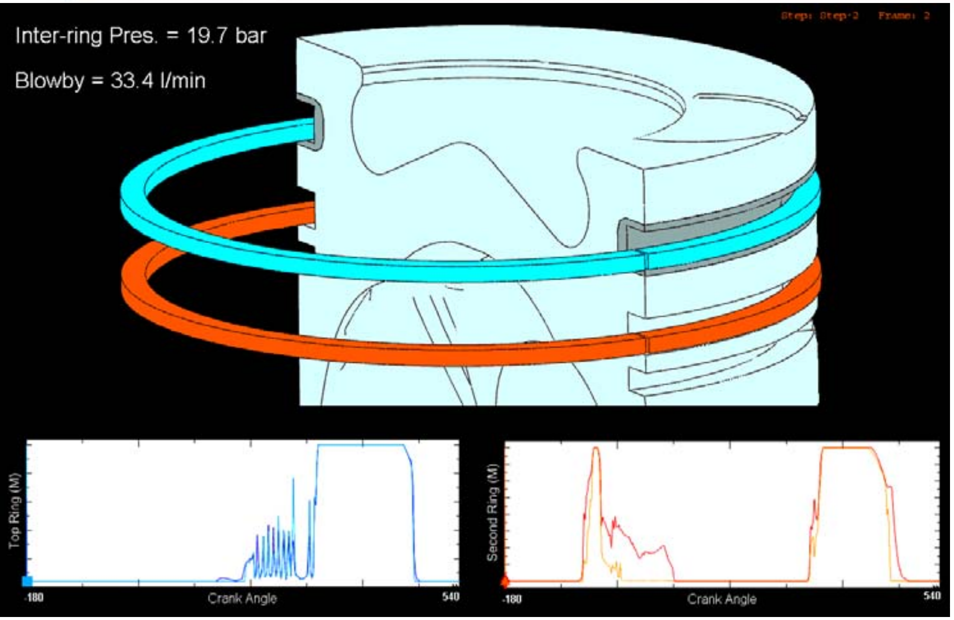
1. basis **2.** optimization 1 **3.** optimization 2

- Reduction of close gap 2nd ring

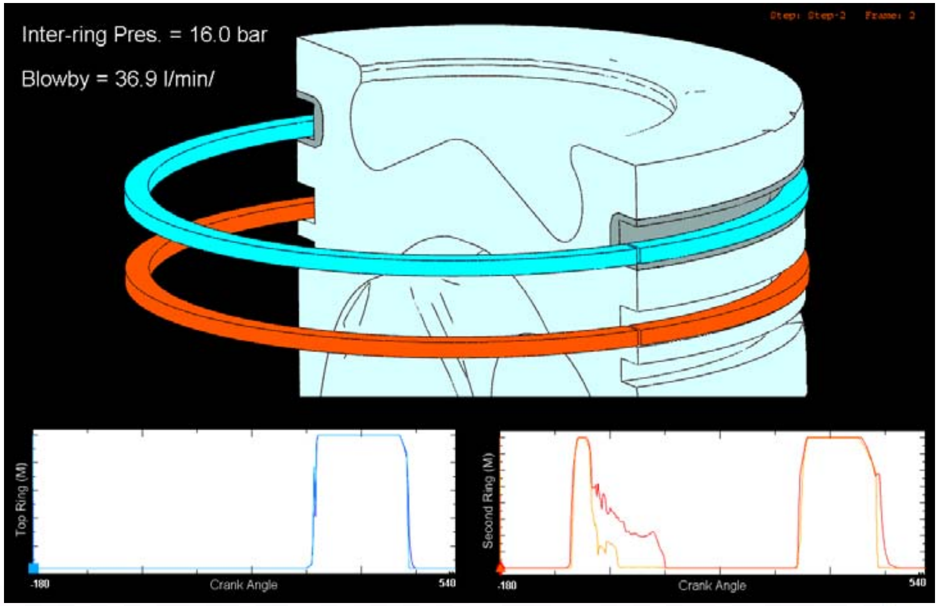
- Reduction of close gap 2nd ring
- optimization of piston 2nd land volume

Animation Axial Ring Motion

Visualization of the movement @ 4600 rpm (2 and 3)



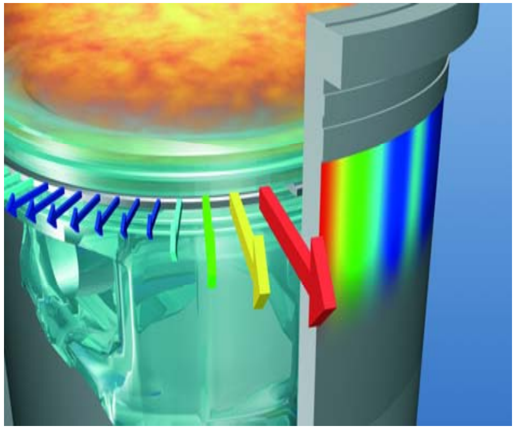
- Optimization 1
- Reduction of close gap 2nd ring
- Blow-by 33.4 l/min
- Inter-ring pressure 19.7 bar



- Optimization 2
- Reduction of close gap 2nd ring
- optimization of piston 2nd land volume
- Blow-by 36.9 l/min
- Inter-ring pressure 16.0 bar

Summary

- **3D Ring Pack analysis shows the possibility of**
  - prediction of blow-by values without adjusting gas flow factors or engine results
  - results of real twist and piston ring movements to detect wear effects
  - direct optimization of piston ring and piston design to engine requirements



Ring movement may have an effect of the emission values. Effects of blow back can reduce the Blow-by. However the “blow-back” may carry oil with it and adversely affect oil consumption. Also, as the ring twists and arches, it will affect the orientation of the running surface of the ring with respect to the liner. This may affect how well the ring scrapes oil.