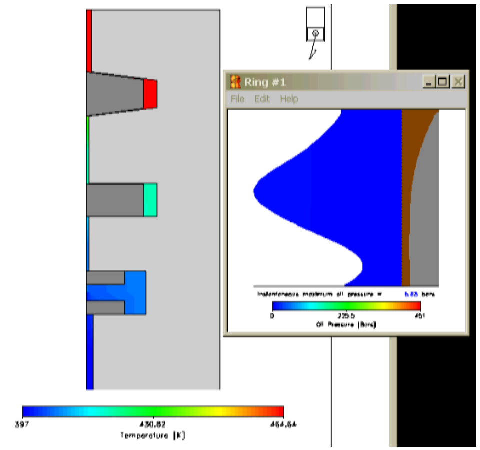
RINGPAK

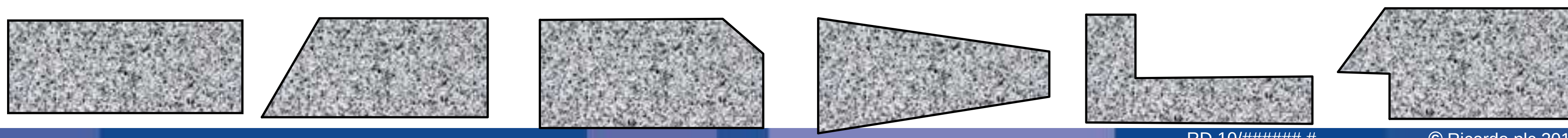
Piston Ring Pack Performance Simulation Software

What is RINGPAK?

- RINGPAK is a simulation package that is used for the design and analysis of a piston ring pack
- The software involves a completely integrated modeling approach to address issues related to friction, lubrication, wear, blow-by and oil consumption
- These intricately coupled phenomena are handled through detailed phenomenological models which enable the user to analyse various aspects of ring pack performance



- Typical applications include
  - Optimisation of a ring pack with relevance to friction, blow-by, oil consumption and wear
  - Influence of oil properties on ring pack performance
  - Parametric studies for various ring pack configurations
  - Piston crown design
- RINGPAK can be used for design optimisation or as a powerful troubleshooting utility to avoid expensive testing



RINGPAK

Model

Sample Correlation

Graphical Interface

Friction

Bore Distortion

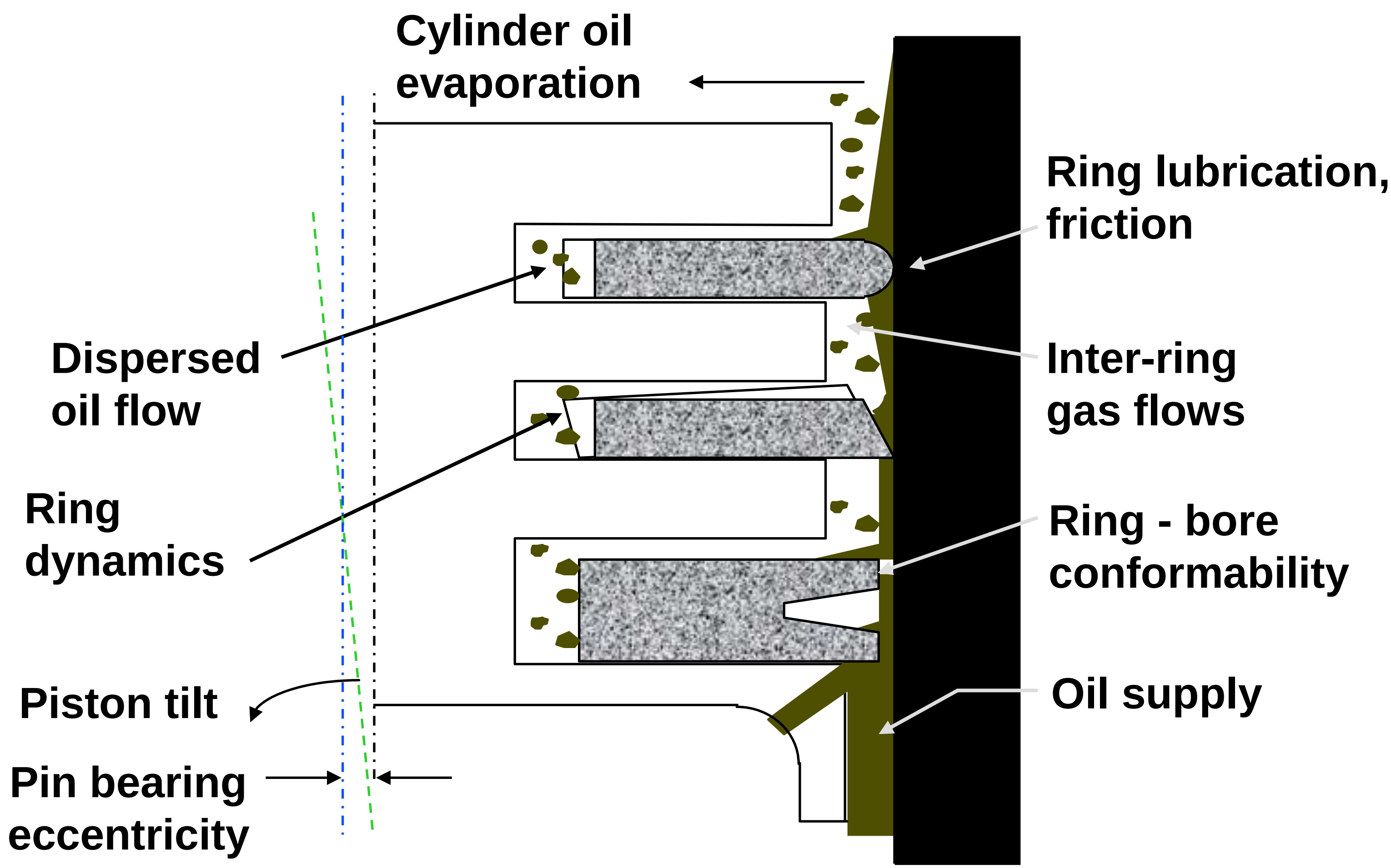
Wear Prediction

PISDYN Interface

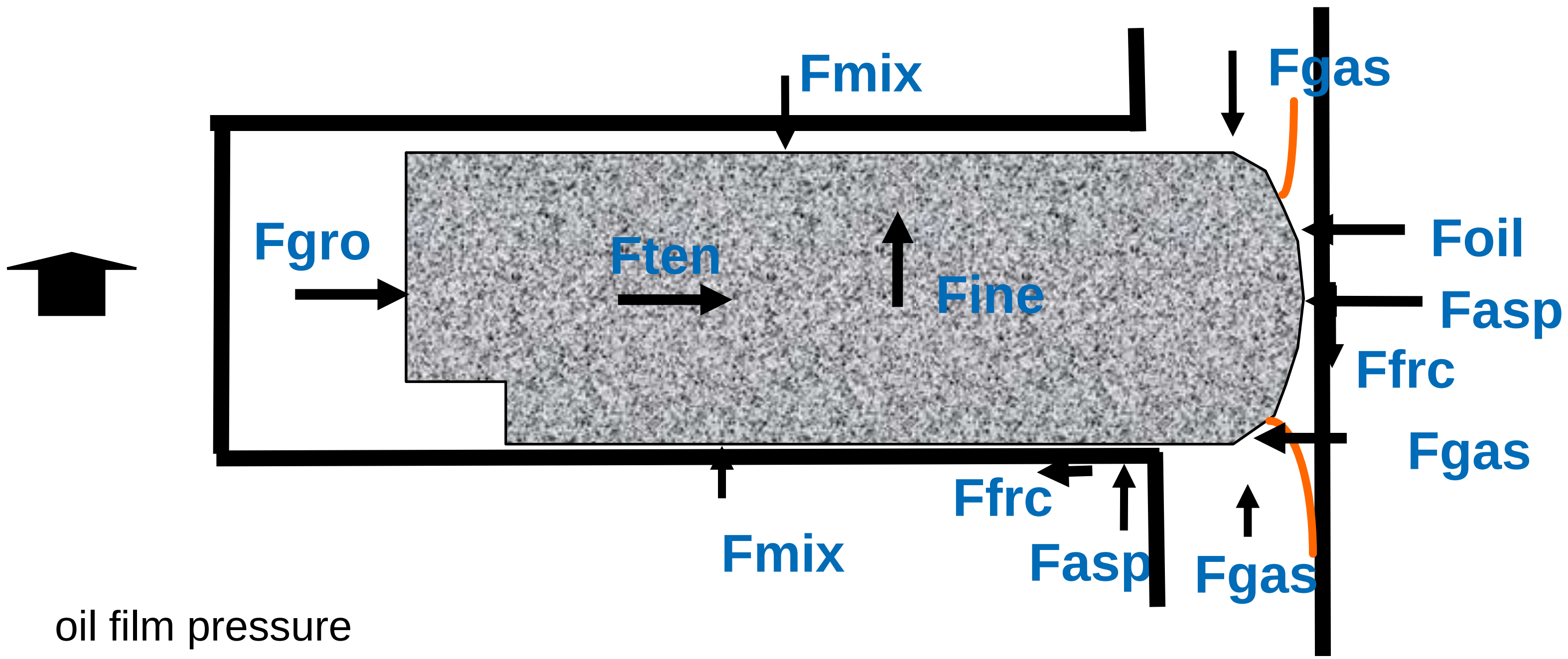
Summary

Ring Pack Phenomena

- Axi-symmetric, 2-D treatment
- Including 3-D features.



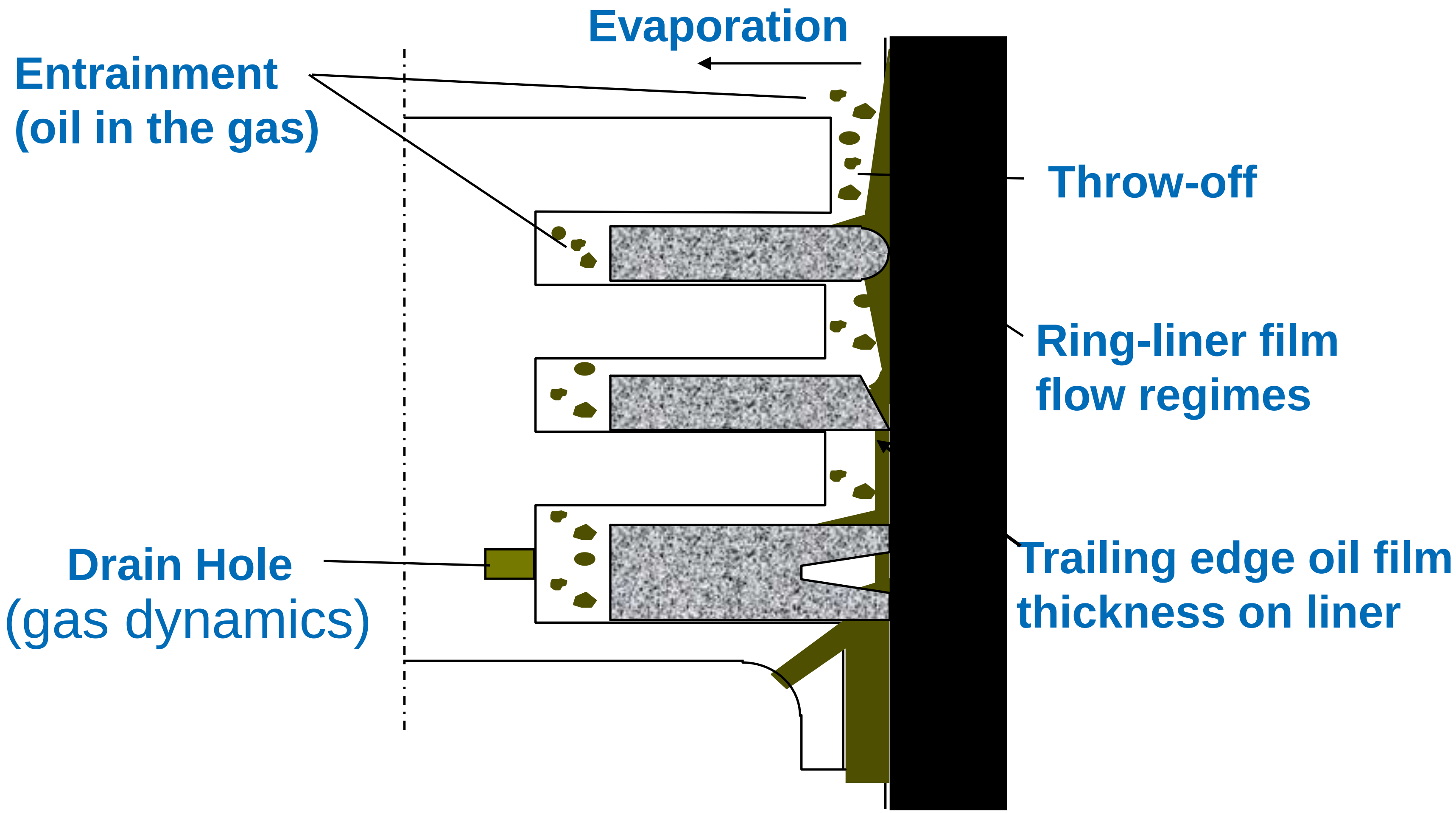
Ring Forces



- Key:
  - Foil: oil film pressure
  - Fasp: asperity contact
  - Fmix: oil-gas mixture in ring-groove clearance
  - Fgas: gas pressure
  - Ffrc: friction at ring-groove interface
  - Fine: inertial force on the ring
  - Ften: installed tension force of ring
  - Fgro: groove gas pressure

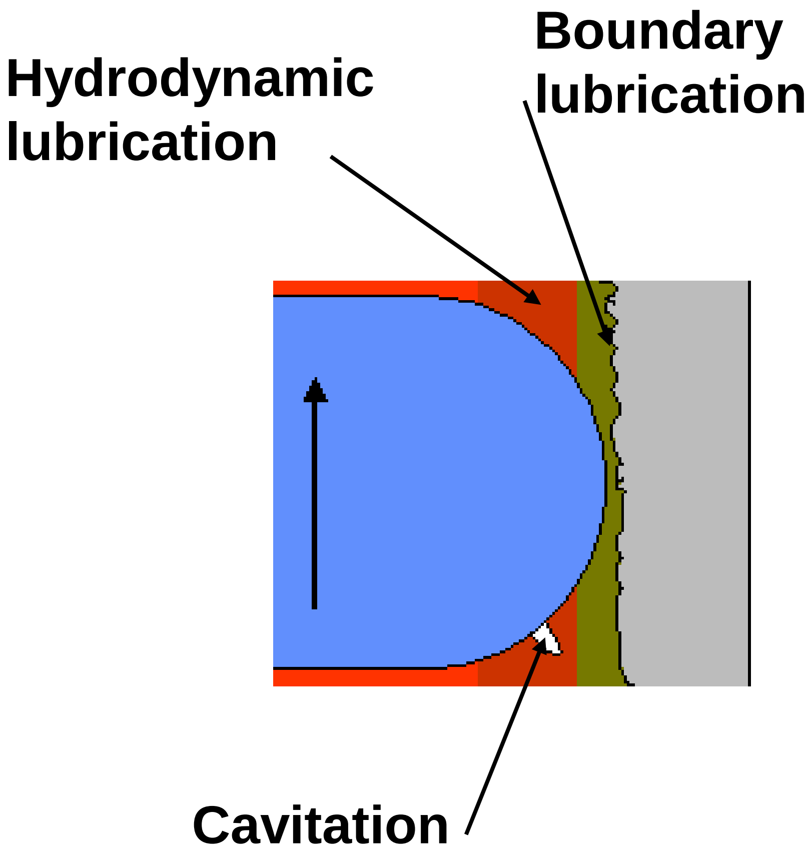
Oil Transport Model

- Mass conserving algorithm



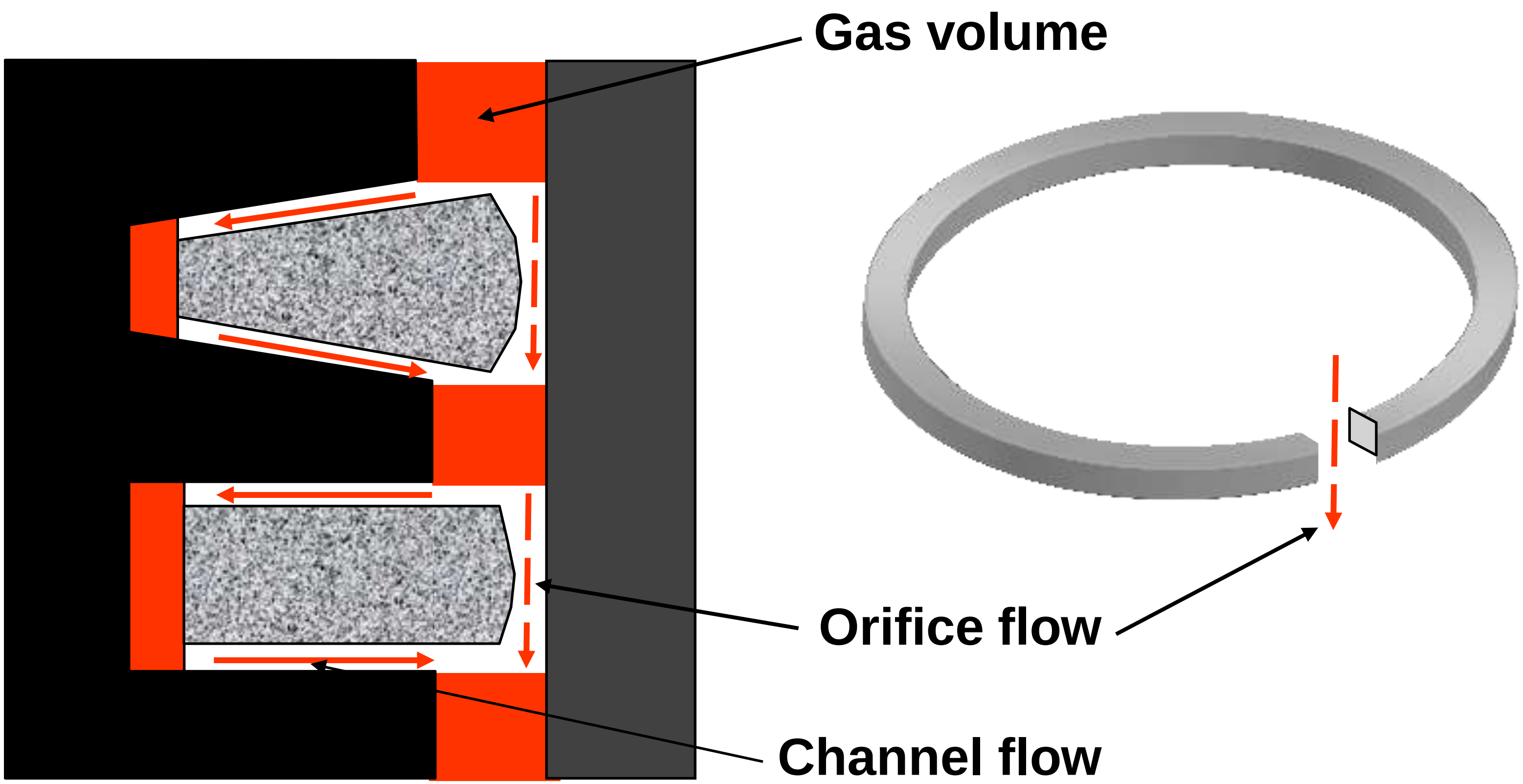
Lubrication Solution

- Sufficient oil film
  - Hydrodynamic lubrication
    - Solution of Reynolds Equation
  - Oil film pressures dependent on clearance, sliding velocity and viscosity
- Reduced oil film
  - Boundary lubrication
    - Greenwood-Tripp model
  - Less oil film support
    - Asperity contact + wear
    -
- Film ruptures
  - Reynolds cavitation boundary model
    - Gas and vapor at pressure less than gauge



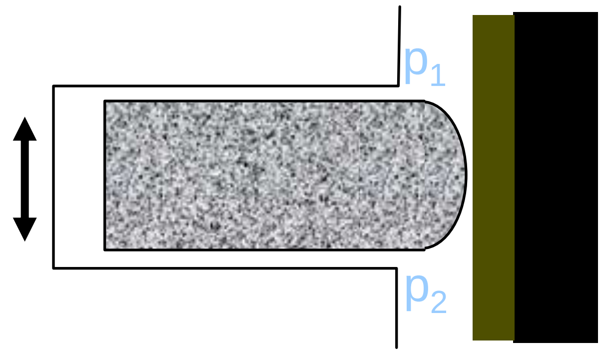
Gas Dynamics

- Channel flow
- Orifice flow (end gap/ ring lift/ non-conformance)

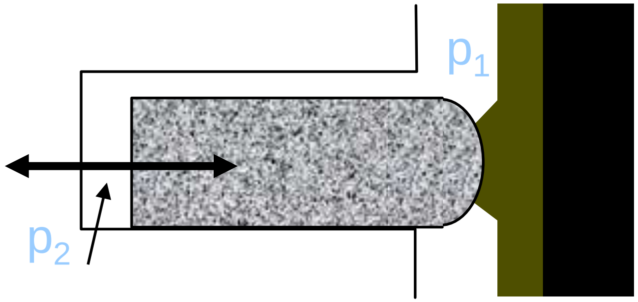


Ring Dynamics

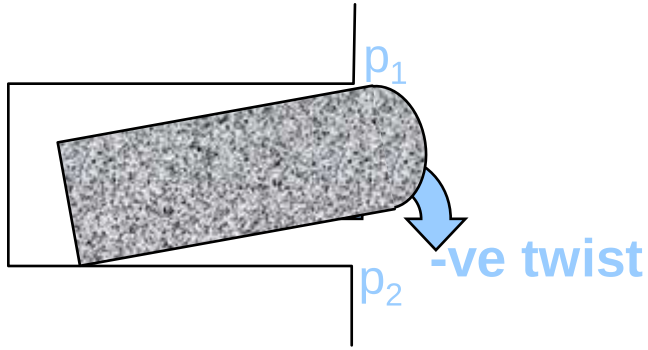
- Ring Axial Flutter



- Ring Radial Lift
  - high combustion gas pressure
  - low land pressure p2 : p1>>p2



- Twist
  - top ring pre twist +ve

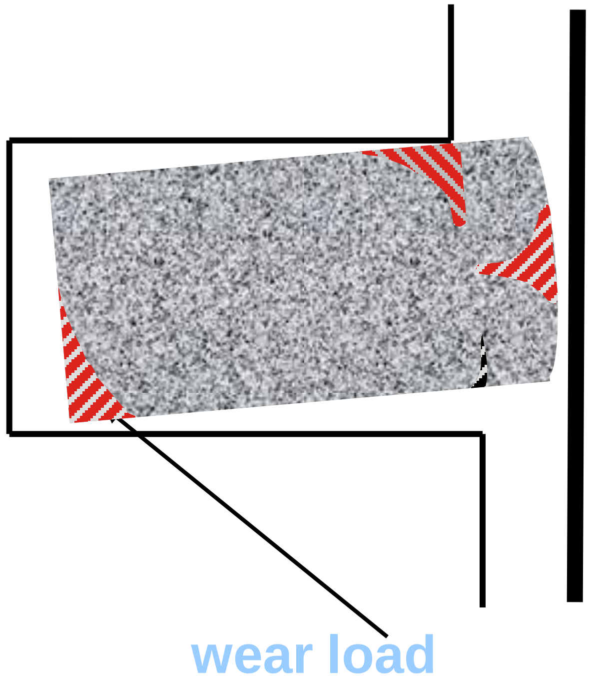


Wear

- Between surface interfaces
  - ring-liner interfaces
  - ring-groove interfaces

- Wear Load = asperity contact pressure x sliding velocity

  (details viewed in RPLOT)



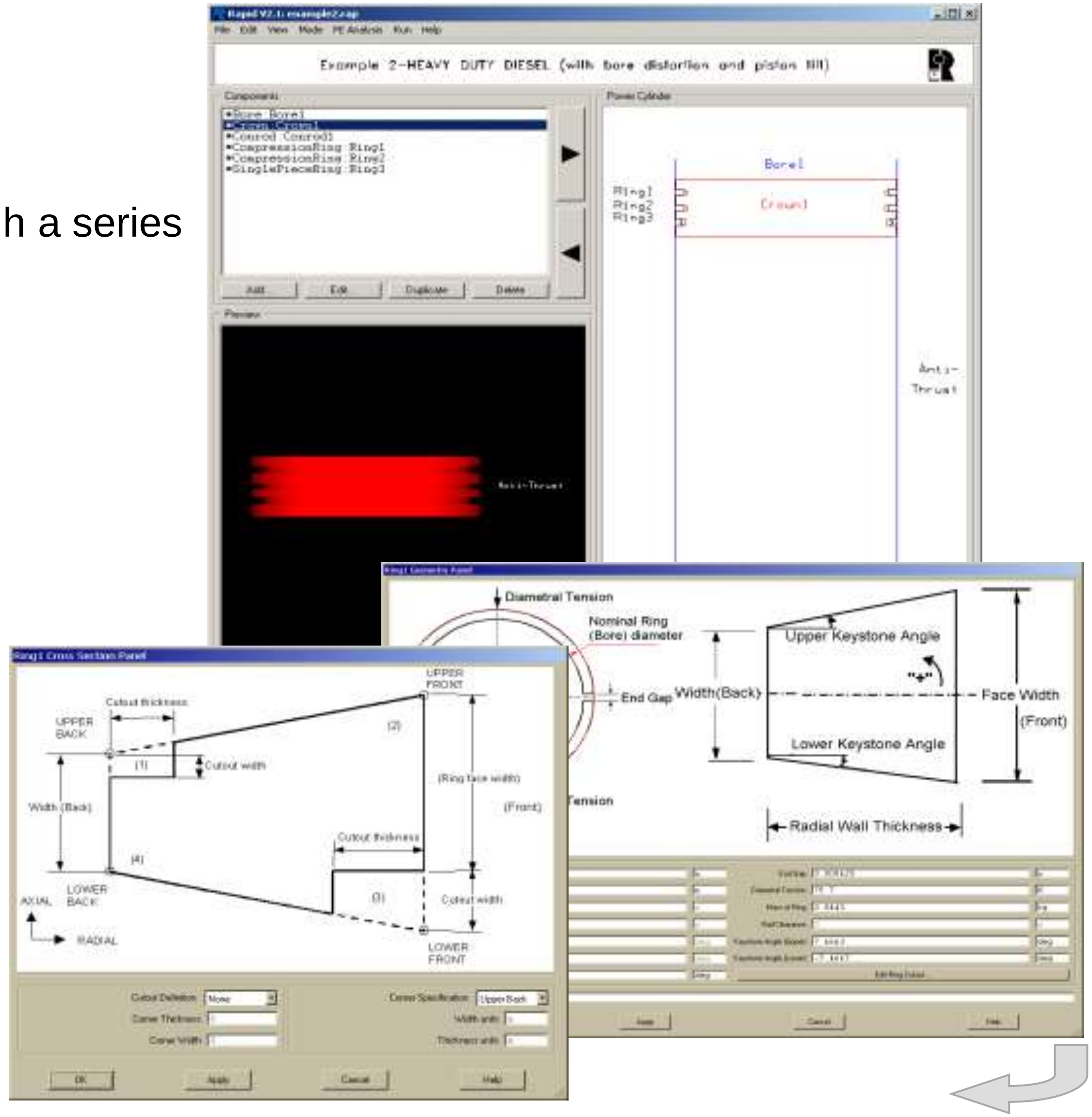
- Wear Rate (.out file) :

$$\text{wear rate} \propto \frac{\text{wear coefficient} \times \text{wear load}}{\text{hardness}}$$

RAPID - Preprocessor

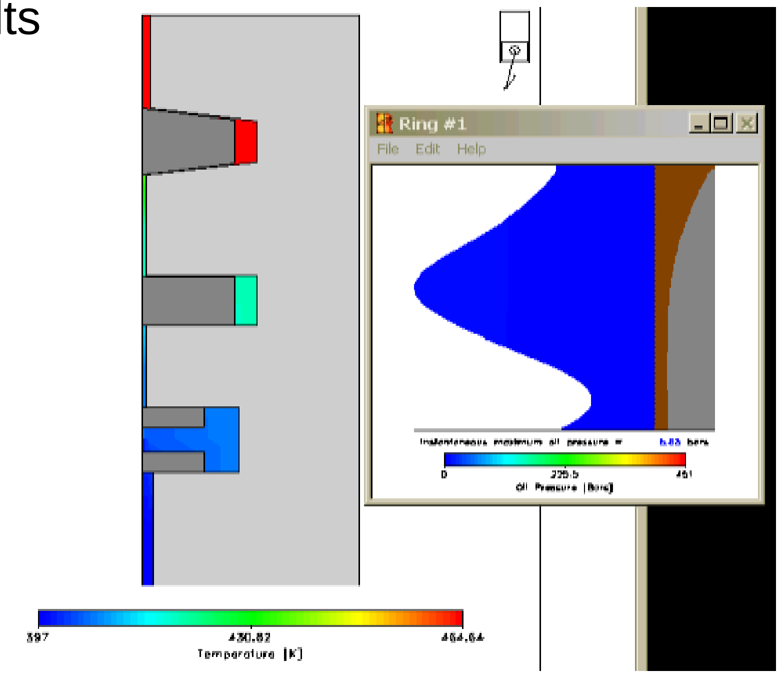
- Rapid is the RINGPAK preprocessor GUI
- This is shared with PISDYN

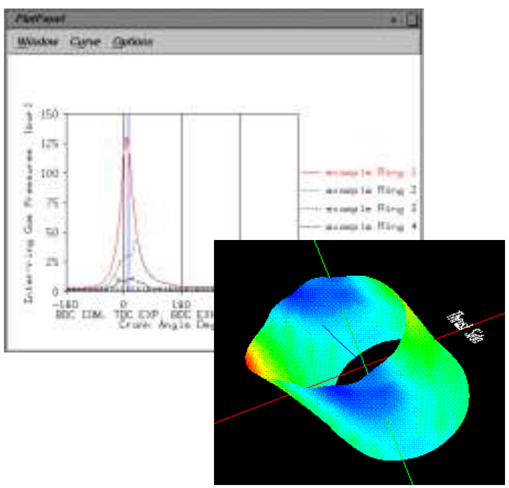
- RAPID allows a user to input key data through a series of panels
- Required Input Data:
  - Geometry (ring, groove etc.)
  - Engine (bore, stroke etc.)
  - Operating Conditions
  - Lubricant
    - Library of SAE grades or user defined
  - Wear Parameters
  - Surface Roughness
  - Oil Transport
  - Evaporation (oil)
  - Simulation
  - Bore Distortion (Optional)
  - Piston Tilt (Optional)

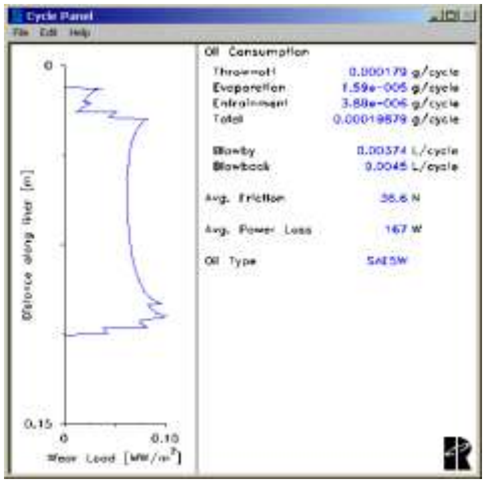


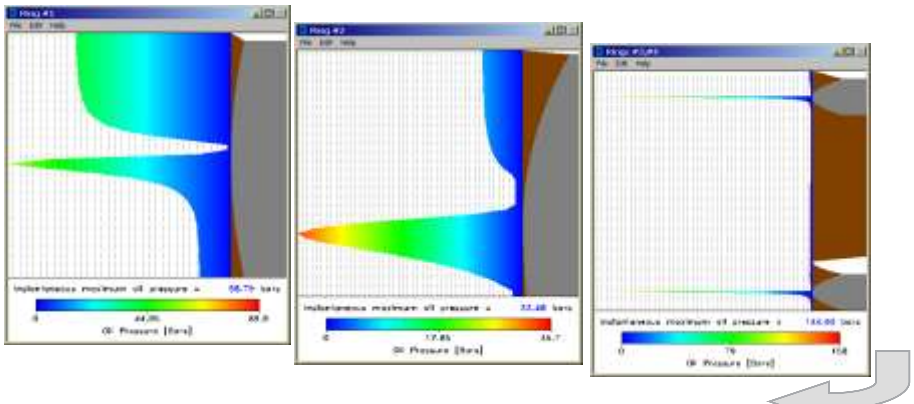
Post Processor GUI

- The RINGPAK postprocessor GUI allows the user to quickly create and view animations and plots of key results
- Ring pack cross section
  - temperatures
  - pressures
  - mass flows
- Ring face cross section
  - meniscus
  - oil film pressures





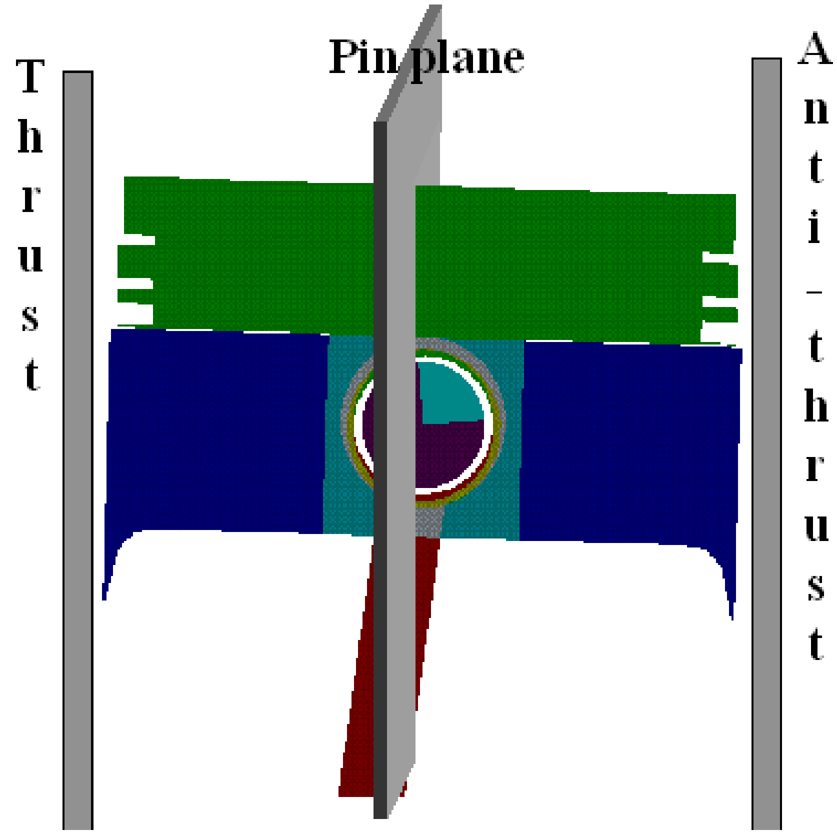




Piston Motion

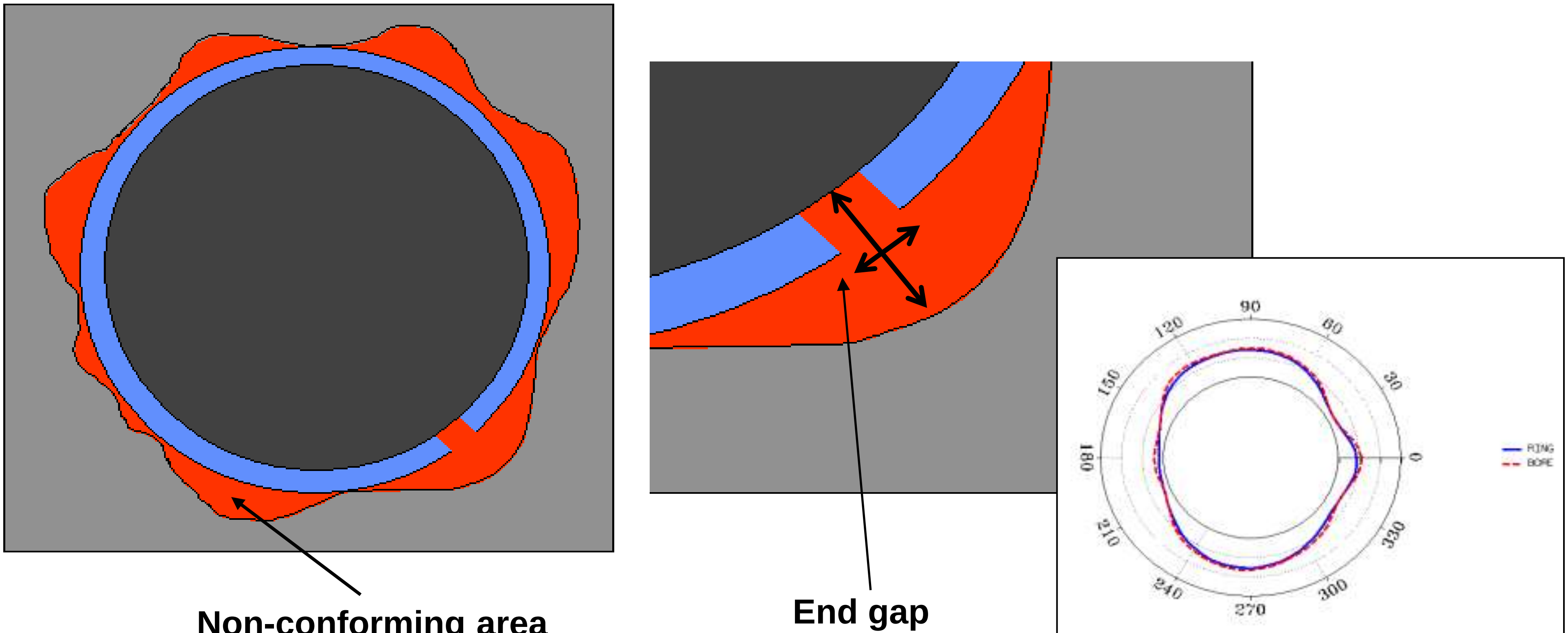
- Optional information

  - Piston tilt and eccentricity vs. crank angle:
    - from simulation, PISDYN
    - measured
    - user data



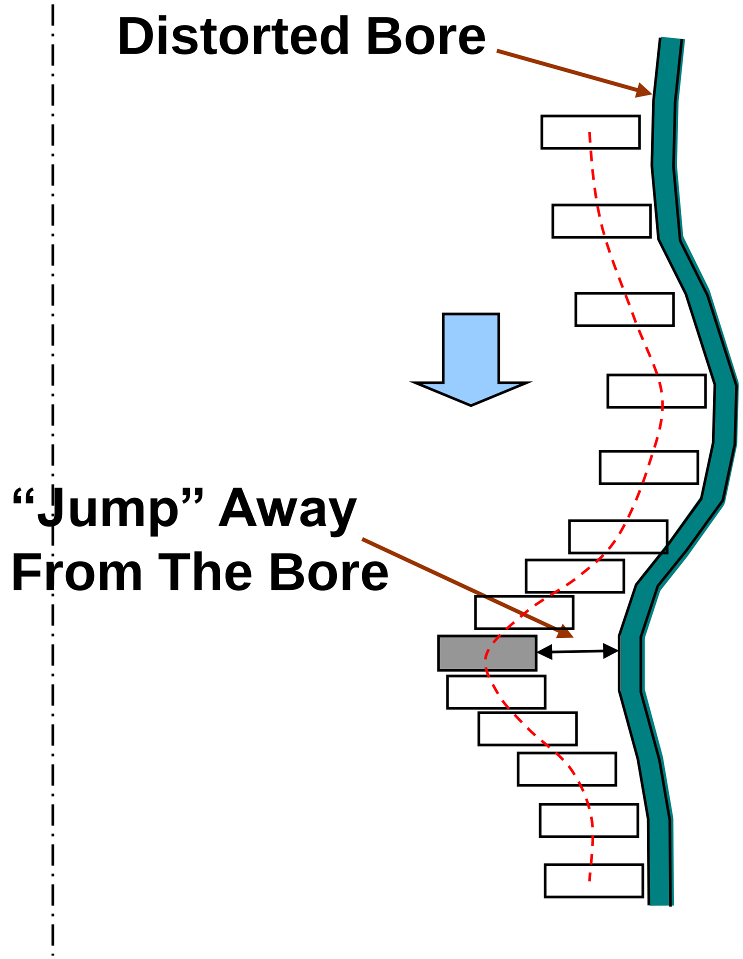
Bore Distortion

- Bore distortion (optional, recommended):
  - measured or FEA
  - radial distortions or harmonic coefficients



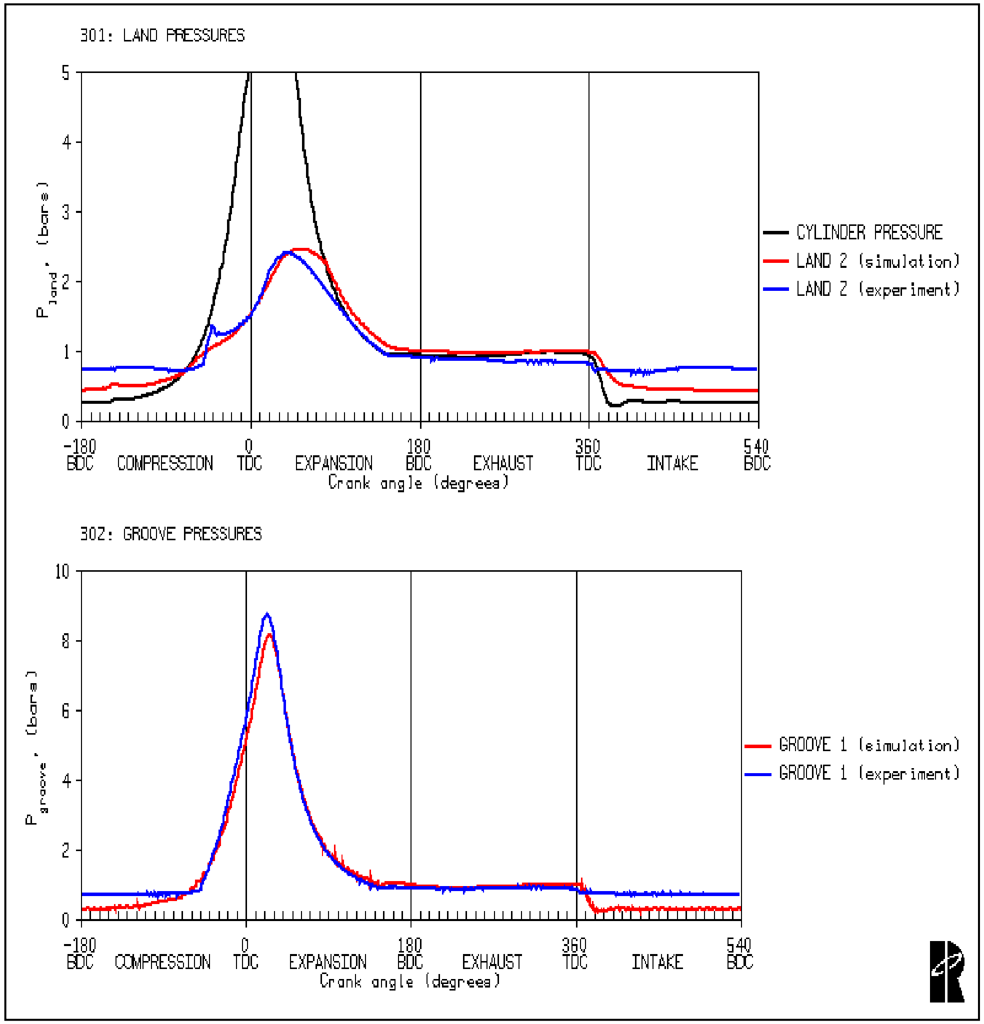
Bore Distortion (axial)

- Axial bore profile:
  - Thermal expansion,
  - Mechanical restraint
  - Wear
- Ring radial dynamics
  - Radial inertia
  - “Ski ramp” effect
- Effects on
  - Oil flow rate
  - Oil consumption
  - End gap / gas flow



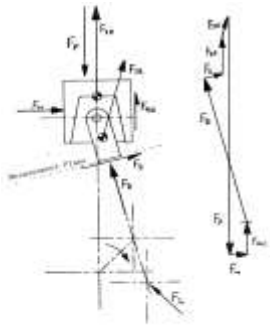
Sample Correlation

- Correlation work by clients for motion, pressure and oil consumption.
- Client Papers
  - Cummins
  - Federal Mogul
  - Metal Leve
- DOE funded correlation, testing done by CAT

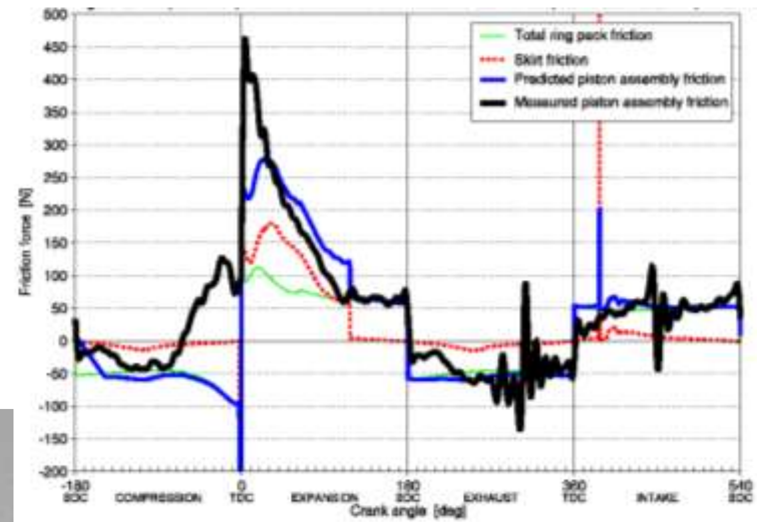


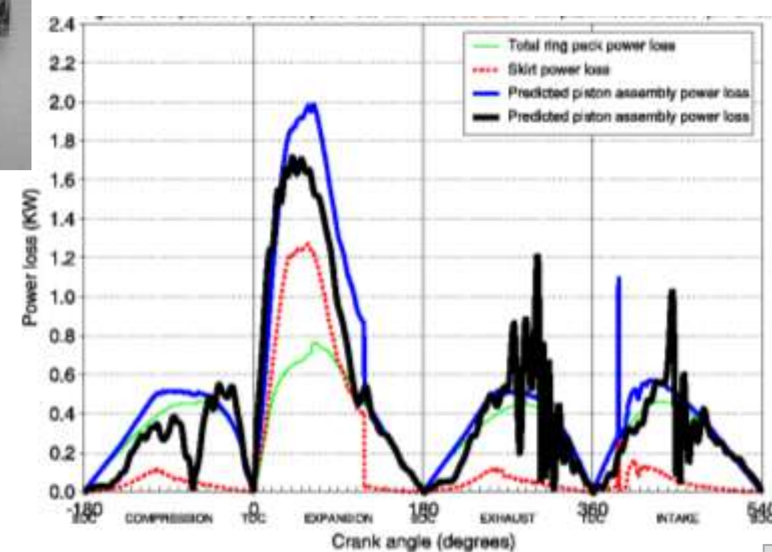
Piston Assembly Friction Validation

- Graphs show good correlation between measured piston assembly friction force and sum of predicted values for rings and skirt at 2000 rpm full load
- Measurements
  - IMEP Method
  - Error at the end of the compression stroke
- Parametric studies performed to quantify the influence of
  - Engine load
  - Engine speed
  - Skirt surface roughness
  - Oil temperature
  - Liner surface texture
  - Boundary friction coefficient
  - Oil grade



- Presented at SAE (SAE 2006-0-0426)
- Further work is planned to quantify the influence of skirt flexibility, skirt profile, ring face profiles and bore distortion





Summary

- World wide user base
- Advanced 2-D Solutions
  - wear and scuffing
  - ring motion
  - oil consumption
- Includes 3-D features
- Oil consumption
- Improved ring pack/piston selection
- Validation by Ricardo and clients world wide
- Reduction in costly testing leading to lower product cost