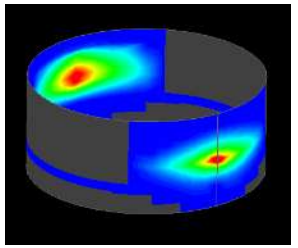
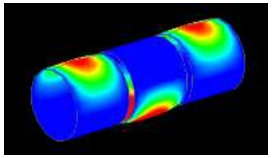
PISDYN

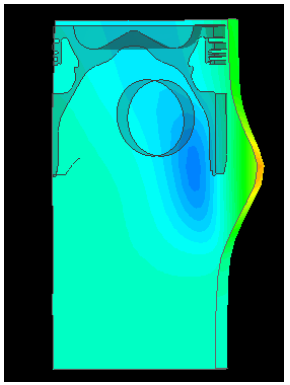
Piston Secondary Dynamics and Skirt Lubrication Simulation Software

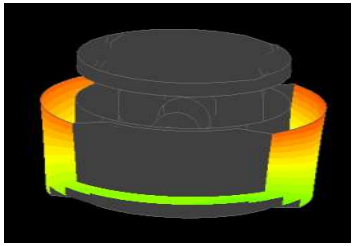
What is PISDYN?

- PISDYN is an advanced simulation package for the design and analysis of piston assemblies
- Simulates the lubrication of the piston-liner interface and the wrist pin bearing
- PISDYN calculates the forces, torques and secondary motions of the piston, wrist pin and connecting rod as a function of crank angle over a complete engine cycle
- The following design parameters can be optimized :
  - Piston Assembly Mass and Pin Offset
  - Skirt Profile, Wall Thickness and Patch Area
  - Skirt-Bore cold clearance
  - Pin bearing
- Typical predictions include
  - Wear, contact and scuffing
  - Friction loss
  - Kinetic energy
  - Piston slap
- PISDYN can be used for design optimization or as a powerful troubleshooting utility to avoid expensive engine testing

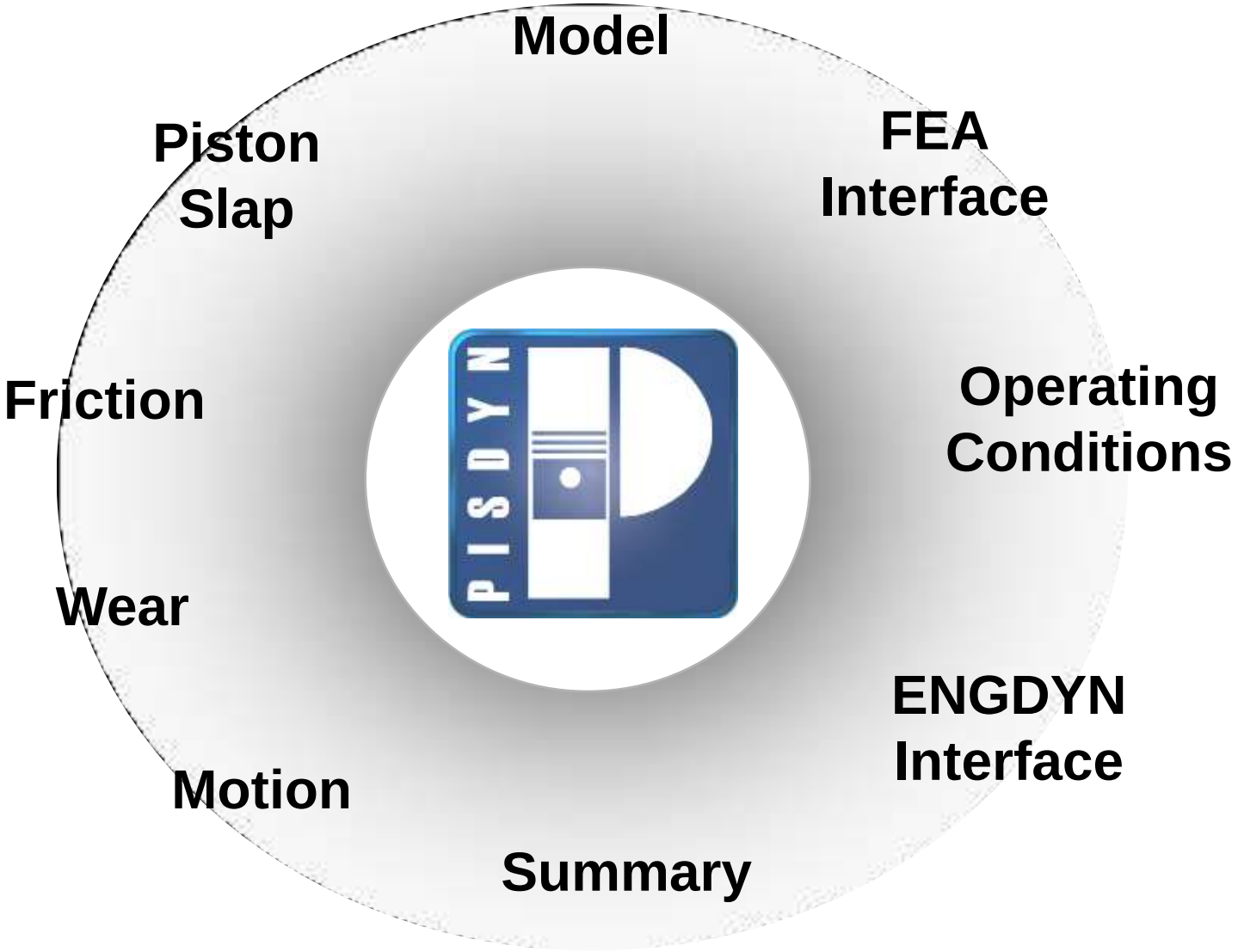




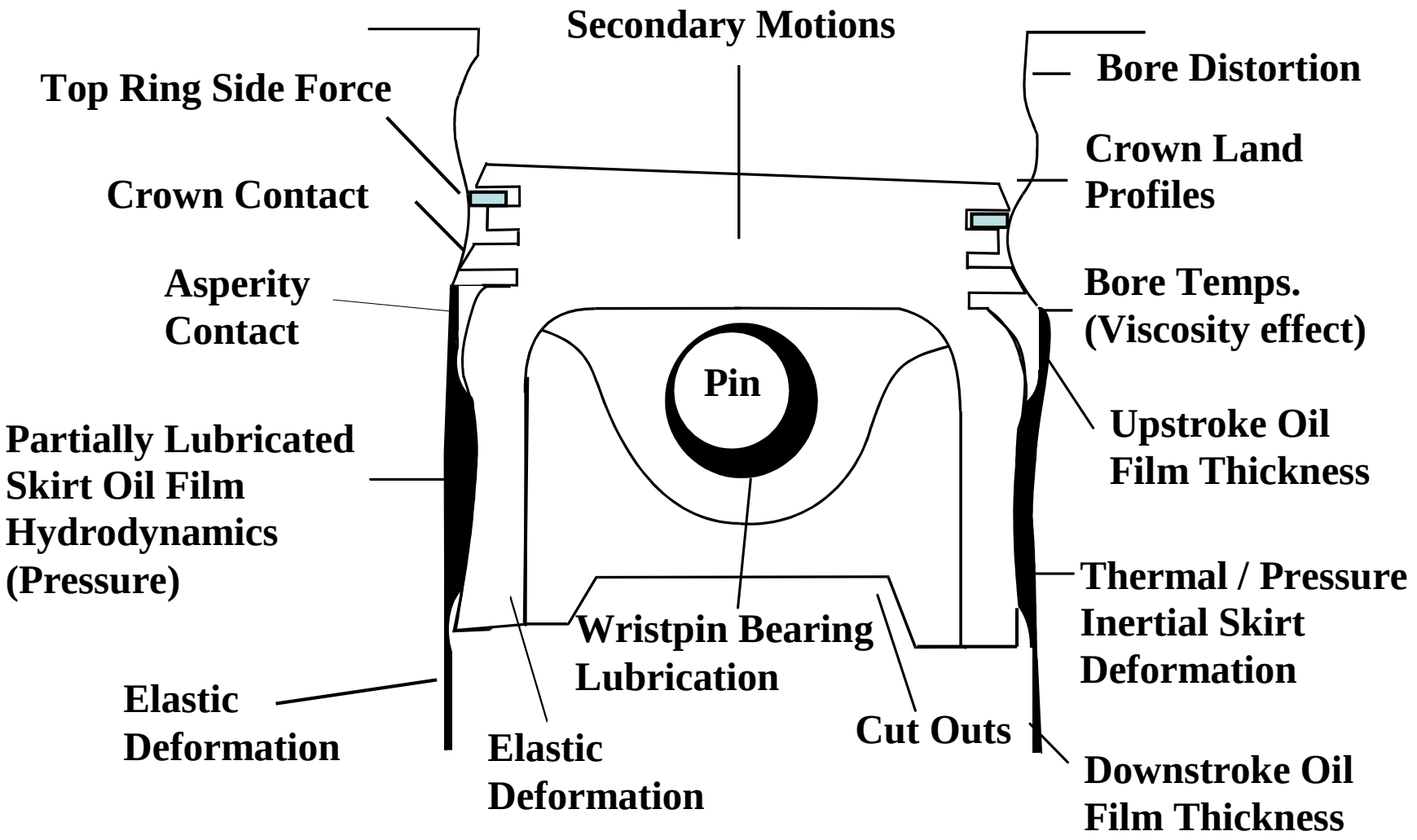




PISDYN

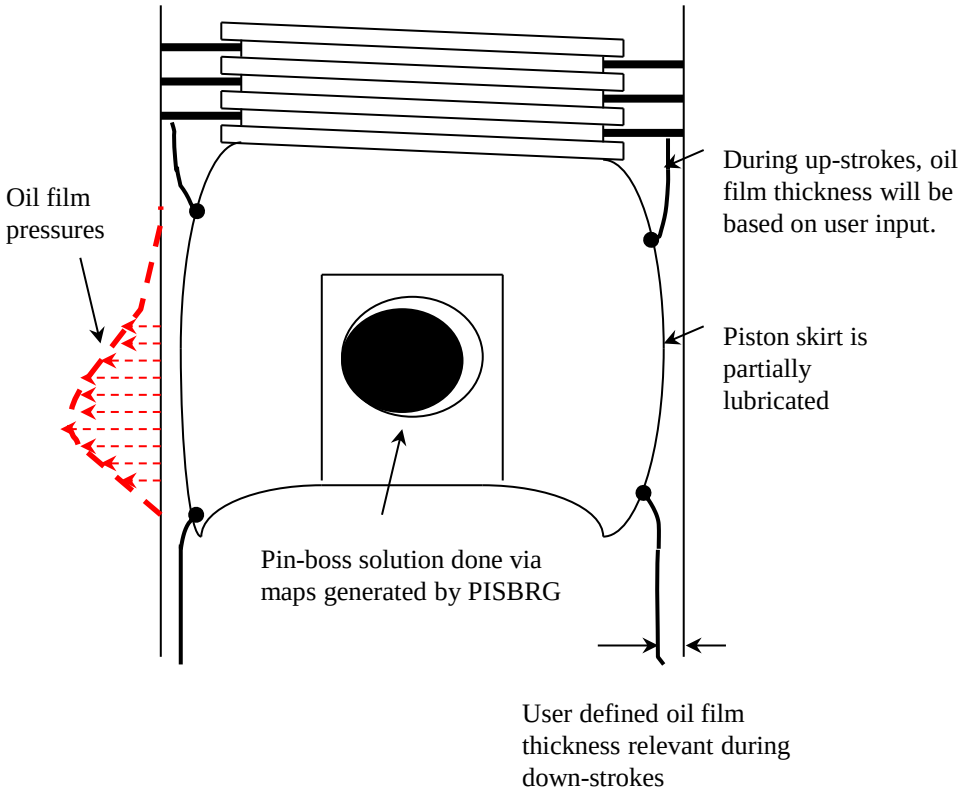


PISDYN Solution Overview



Partial Lubrication Model

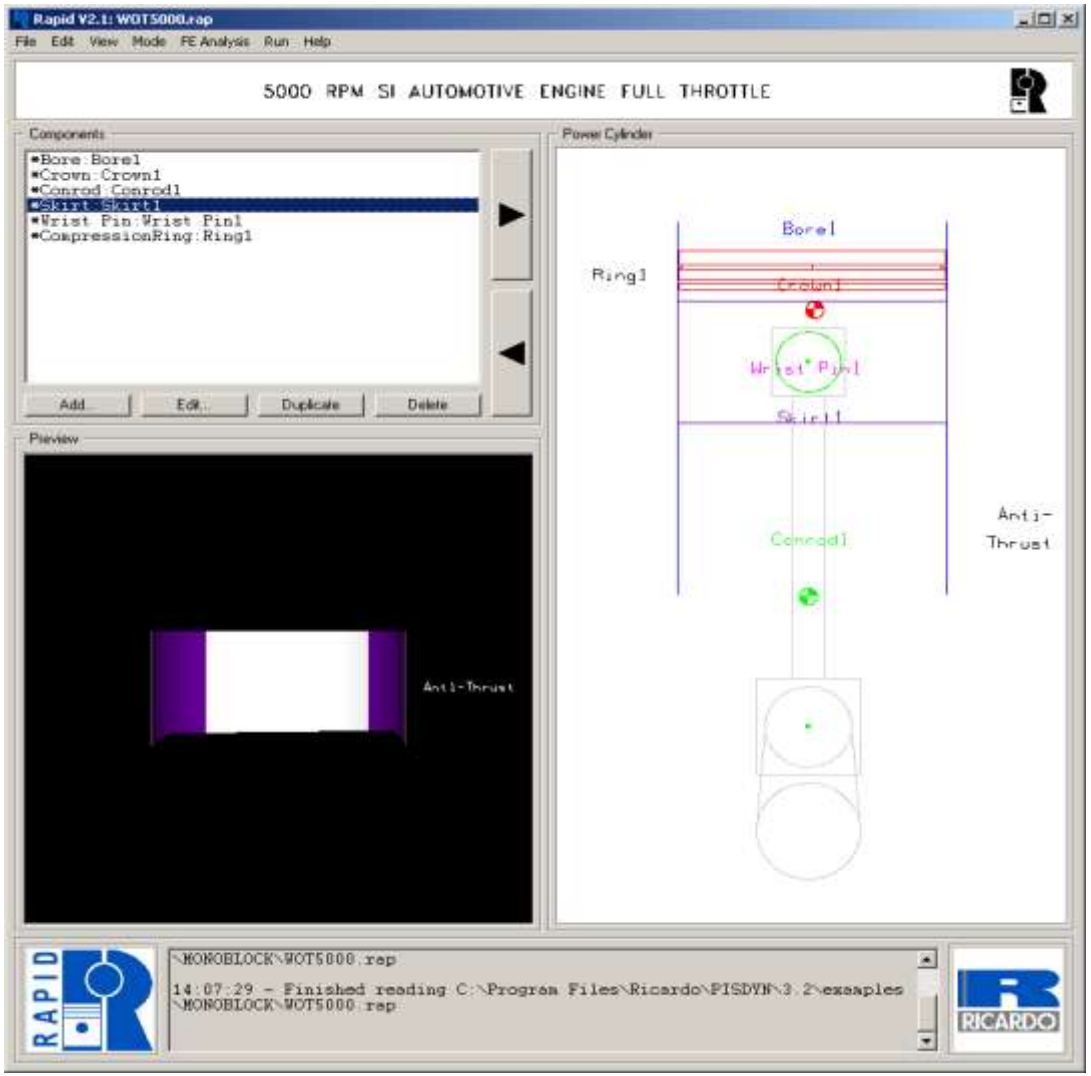
- Partial Lubrication Model
  - Integration of orbit solver
    - Mass conversing finite volume solution scheme
    - Hydrodynamic and Boundary Lubrication models
    - Improved treatment of cavitation zones
  - Improved definition of lubricated area
    - 360 deg model (previously 180 deg)
    - Polygon definition of unlubricated zones
    - Asymmetric bore distortion
  - User specifies oil supply on cylinder
    - Constant, or
    - Varying along cylinder
    - Dry and Fully Flooded remain as options
  - Improved clearance predictions
  - Allows top lands to be considered

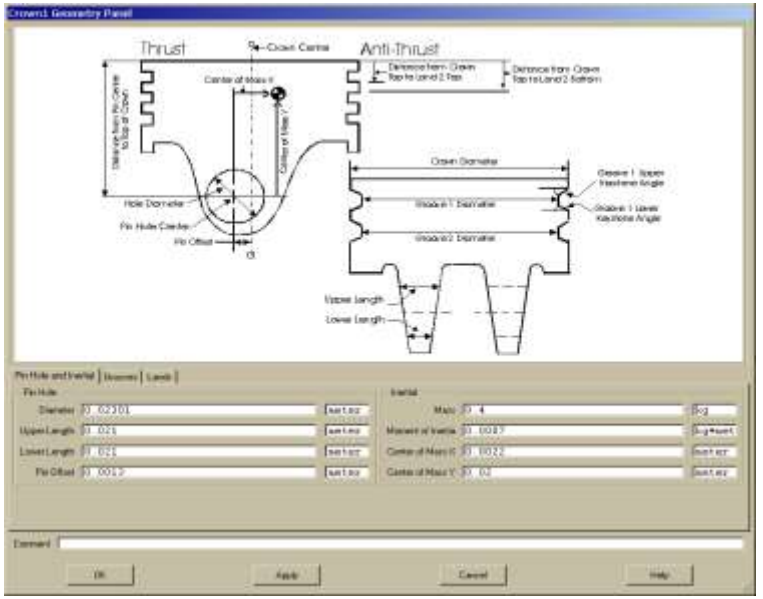


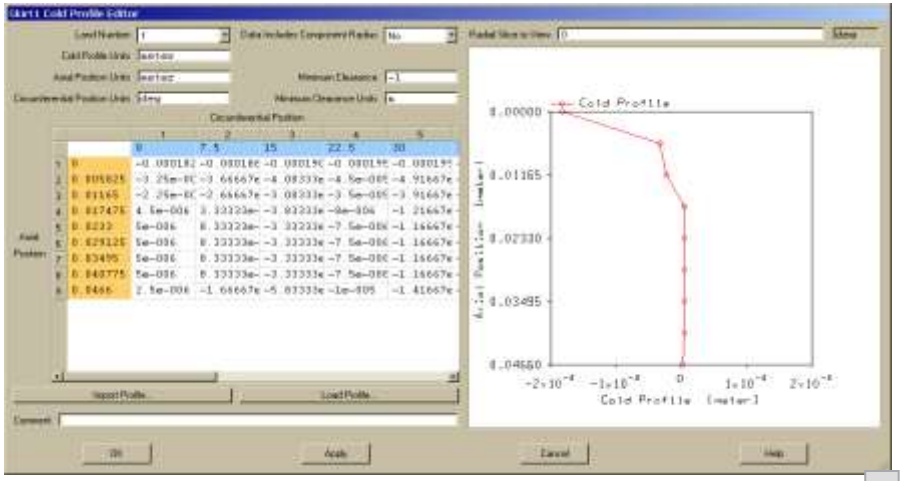
Input Data

- Data from piston design:
  - 3D skirt/crown profile definition
  - geometry of piston, pin, conrod
  - pinbore offset
  - mass, center of gravity, moment of inertia
  - material surface finish (asperity)
- Boundary Condition data:
  - cylinder pressure (different conditions)
  - oil viscosity
  - temperatures
  - bore distortion (measured/predicted @ diff. temperatures)
- This input data allows the user to control concept design or optimization factors such as skirt ovality and piston clearance

RAPID Pre-Processor

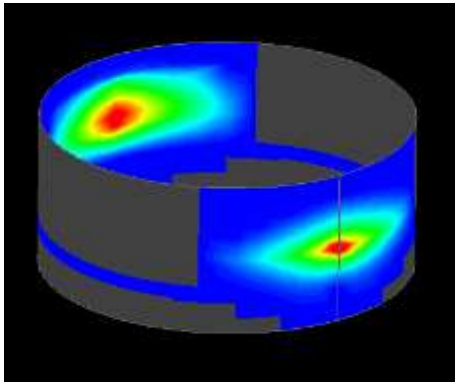


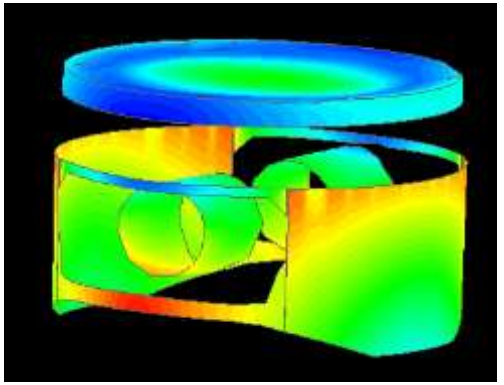


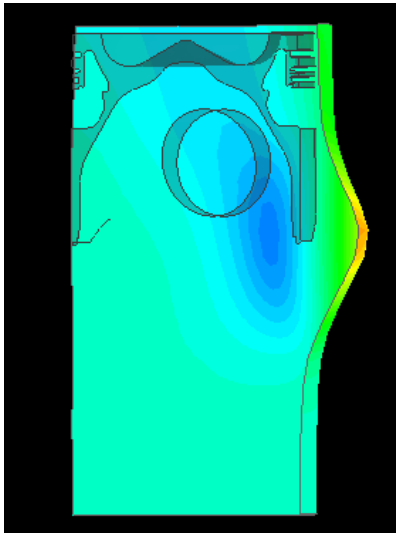


Post Processing: Animation

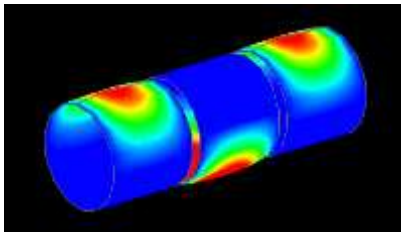
- The post processing utility can be used to make animations of certain key phenomena, such as;
  - clearance
  - void fraction
  - hydrodynamic pressure
  - contact pressure
  - shear stress
  - pin bearing pressures
  - wear loads
  - skirt and liner deformations

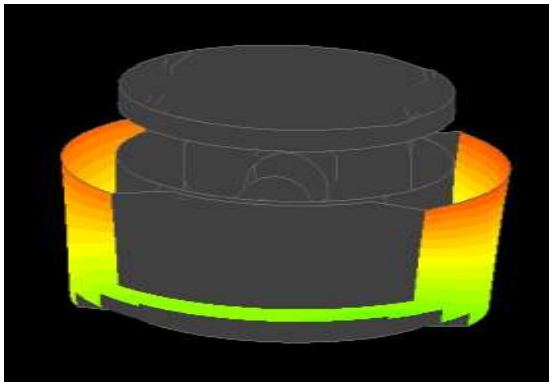






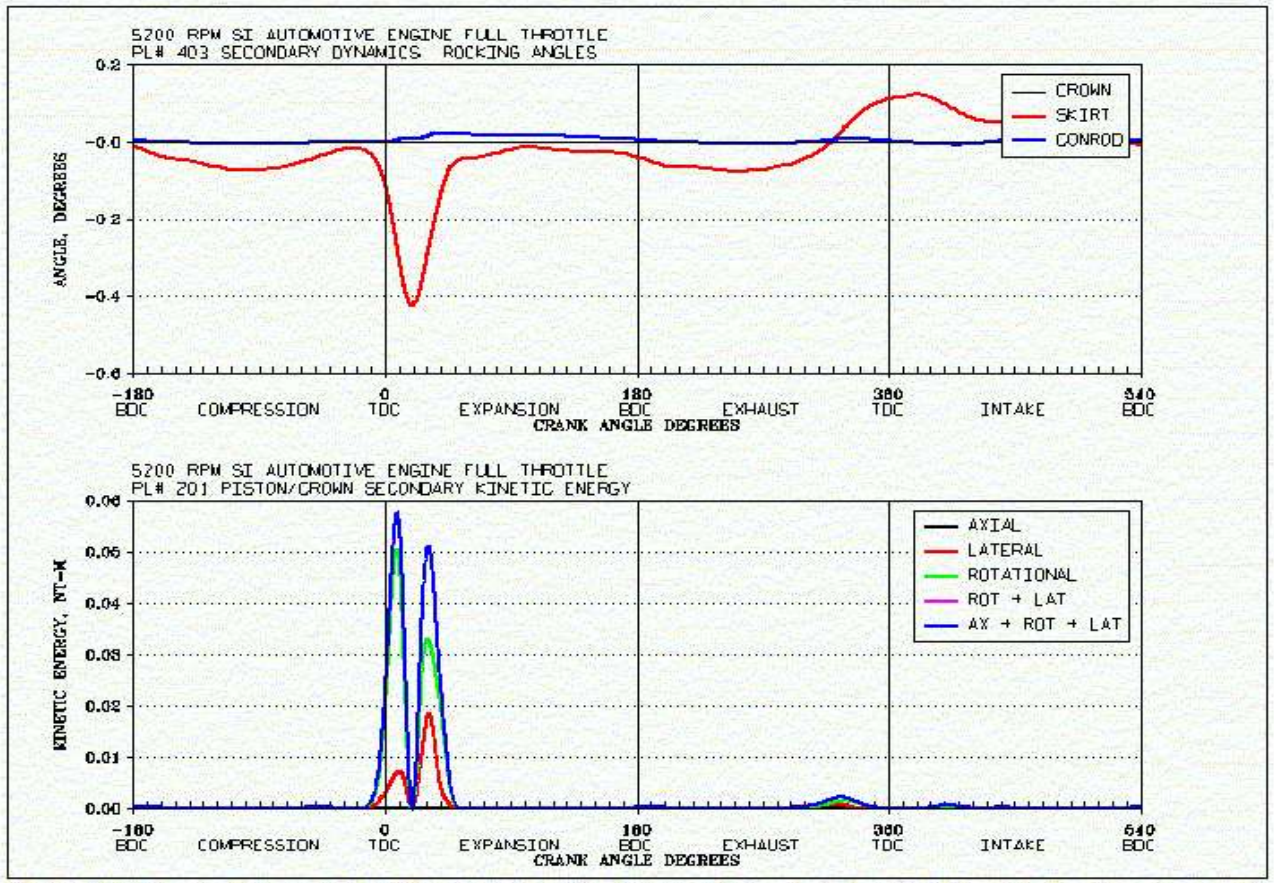
- Liner loads can be output at specific crank angles and applied to liner/block FE models





Post Processing: Plotting

- Using RPLOT cyclic data for the following can be plotted:
  - motion
  - forces
  - moments
  - energy
  - contact
  - deformations

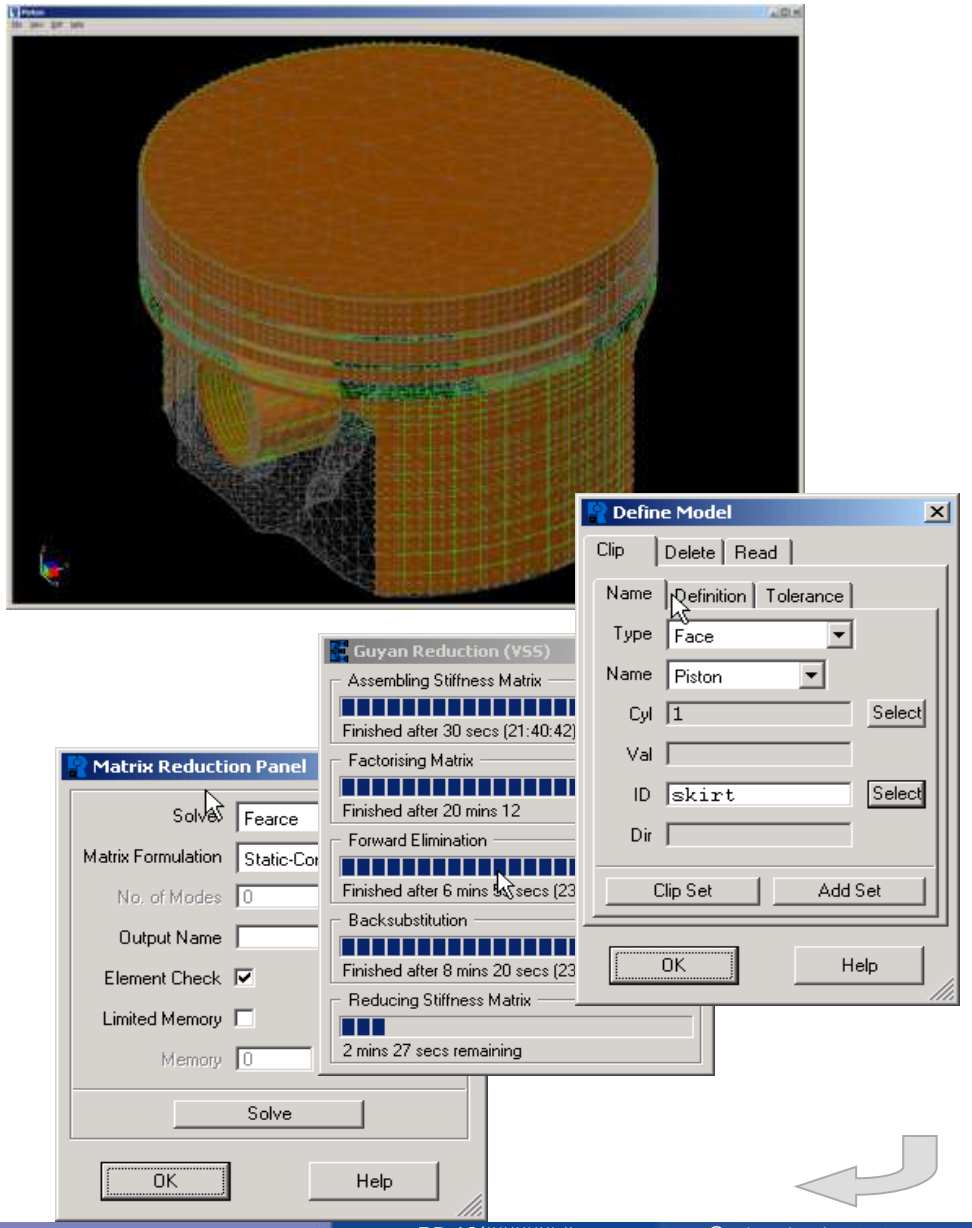


Operating Conditions

- Three key operating conditions:
  - cold piston / cold bore
  - hot piston / cold bore
  - hot piston / hot bore
- Cold piston / cold bore:
  - noise
  - piston slap
- Hot piston / cold bore:
  - top land contact
- Hot piston / hot bore:
  - skirt contact
  - scuffing and wear

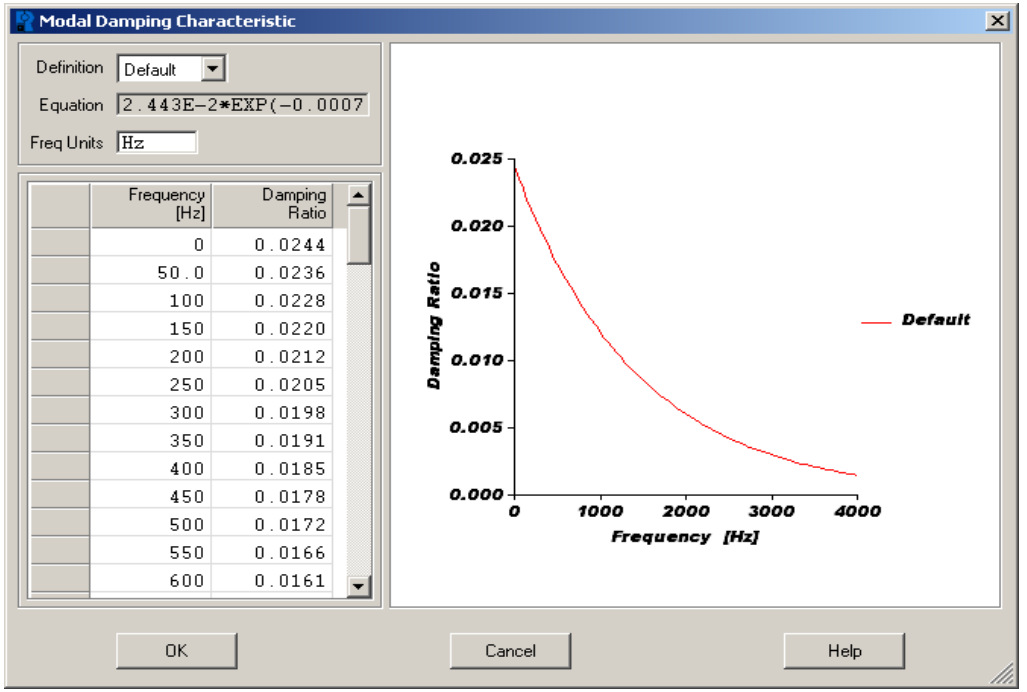
FE Analysis From Rapid Interface

- FE Model Definition and Matrix Reduction from RAPID
  - FEARCE
    - Automatic selection of sets for loading
    - Vectorized Sparse Solver (VSS)
    - Static and dynamic (CMS) reduction
      - Compliant and dynamic models
    - Thermal, inertia and pressure deformation
    - Handling of constraints
    - Temperature dependent material properties
  - Stiffness w.r.t. FE mesh
    - Compliance matrix evaluated w.r.t. lubrication mesh
  - Complete piston and liner models
    - Optional half model
  - Inertia Relief for static models
    - No ‘artificial’ restraints
  - Built in translators
  - Pressure loading of cylinder head (optional)
  - Back-substitution
    - Displacements of complete piston/liner
  - Interface shared with VALDYN and ENGDYN



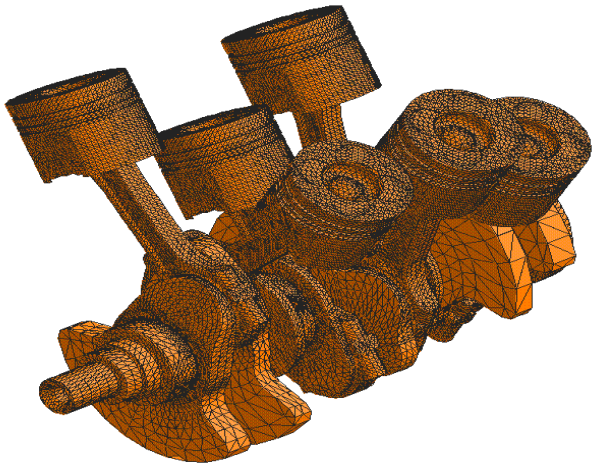
Piston And Liner Dynamics

- Piston and Liner Dynamic Models (both optional)
  - Mass and damping
    - User defines modal damping characteristic
      - Critical damping ratio against frequency
      - Critical damping applied to each mode
  - Component Mode Synthesis (CMS) reduction
    - User selects number of dynamic modes
  - Improved vibration predictions
    - Piston slap predictions

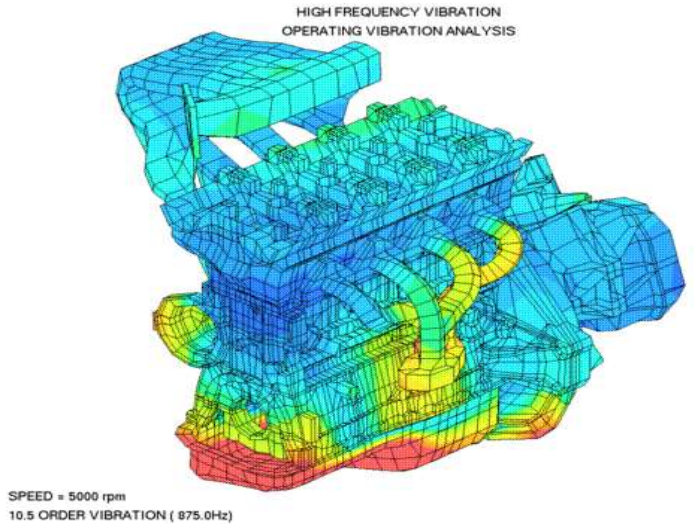


ENGDYN Interface

- Force data can be transferred from PISDYN for the following loads in ENGDYN:
  - Piston skirt loads
  - Piston crown loads
  - Conrod pin bearing load



- The ENGDYN analysis will include the effects of piston slap and noise on the cylinder block within FE static and powertrain dynamics solutions

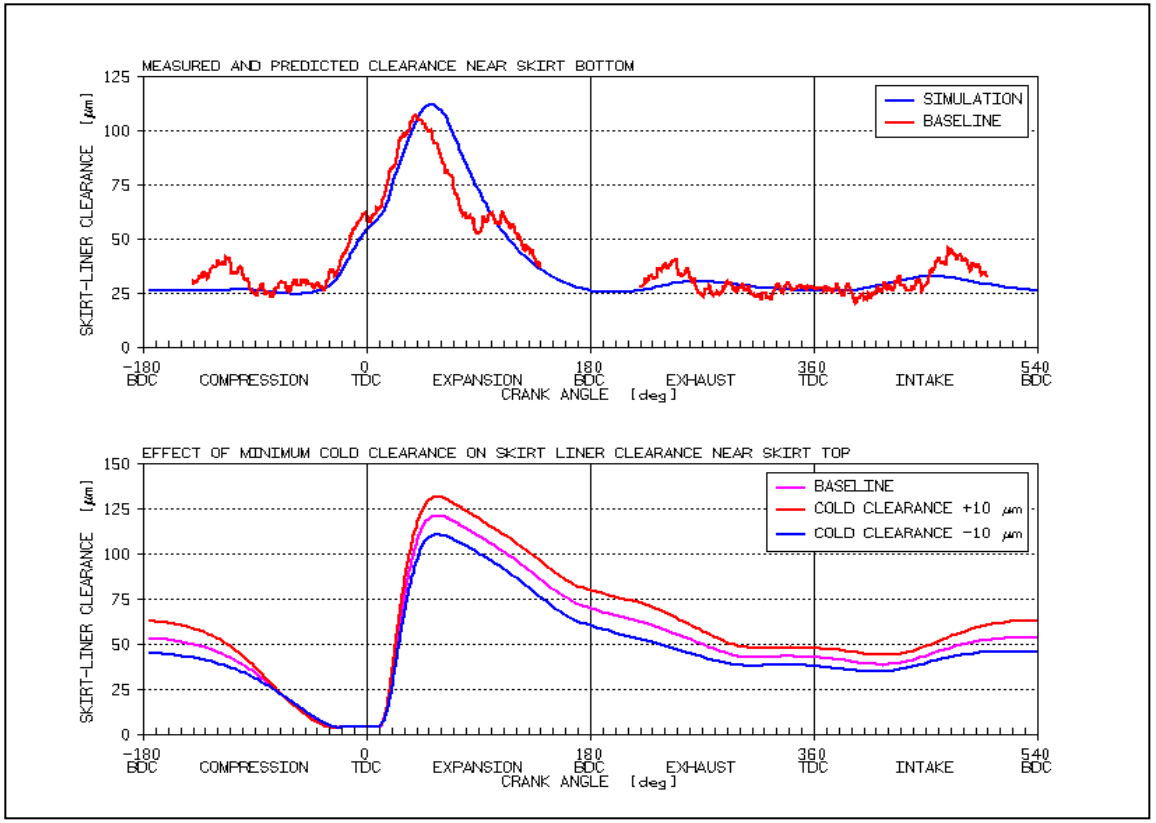


Correlation 1

- ISUZU (1997 RS IUC)

  Comparison of Measured and Predicted Skirt Liner Clearance in a Gasoline Engine

- Result:
  - gap sensors
  - good correlation
  - sensitive to cold minimum clearance

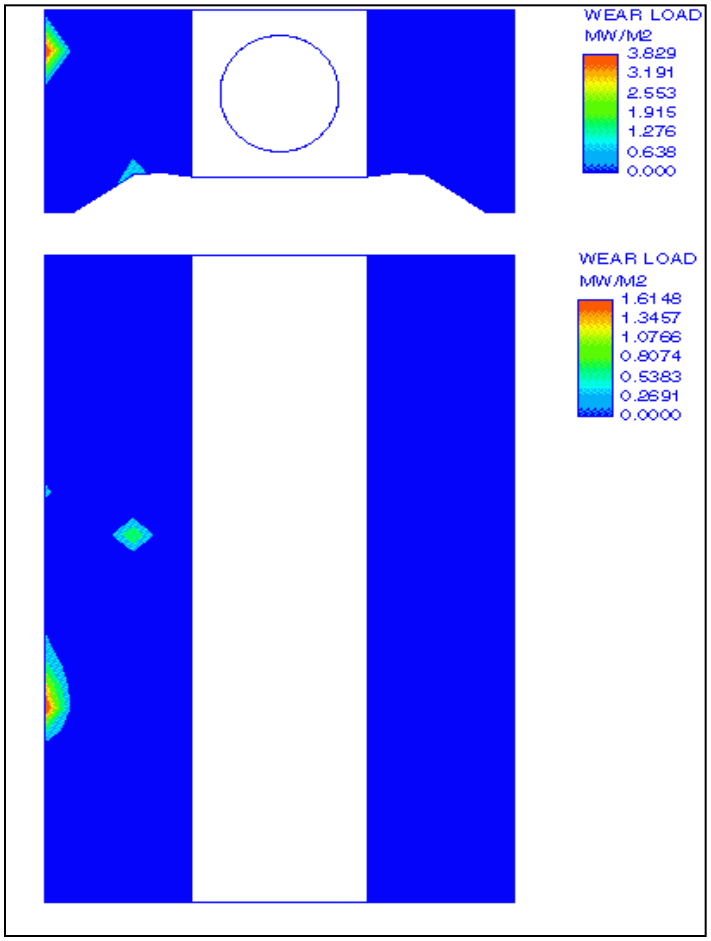


Correlation 2

- PISTONES MORESA

  (1998 RS IUC)
- Correlate wear profile
- Establish contact force
- Reduce skirt contact force

  by skirt profile modification

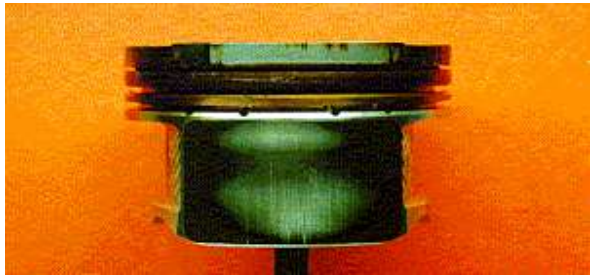


Baseline - high wear

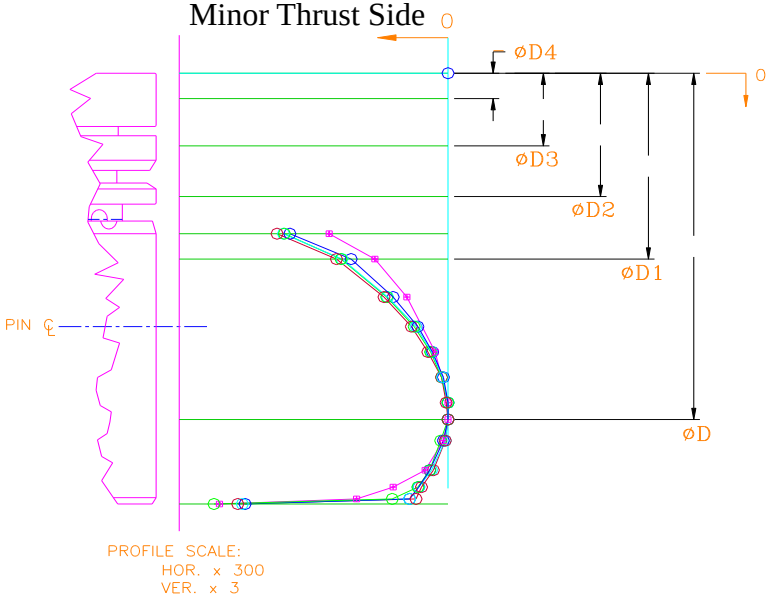
Correlation 3

- Concept to practice (RS IUC99)

Baseline Profile 100 hr Test

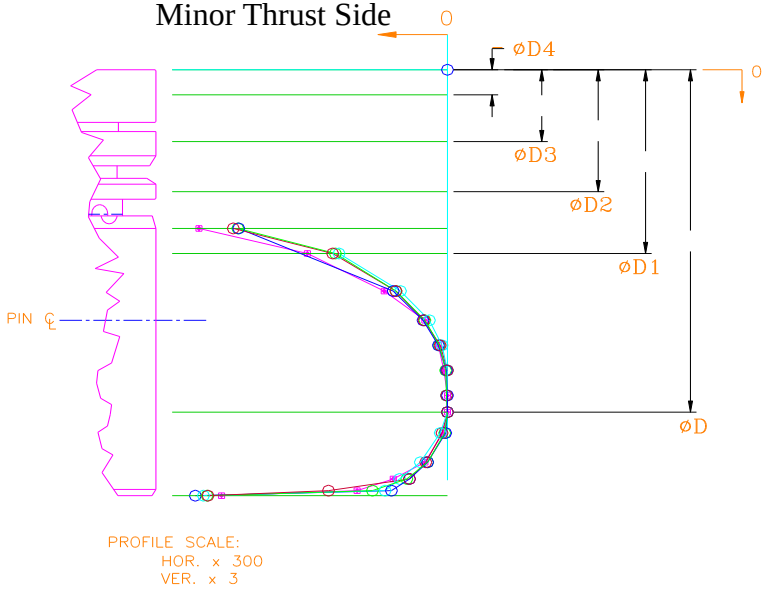


Piston 4
Minor Thrust Side



PISDYN Optimized Profile 100 hr Test

Piston 2
Minor Thrust Side

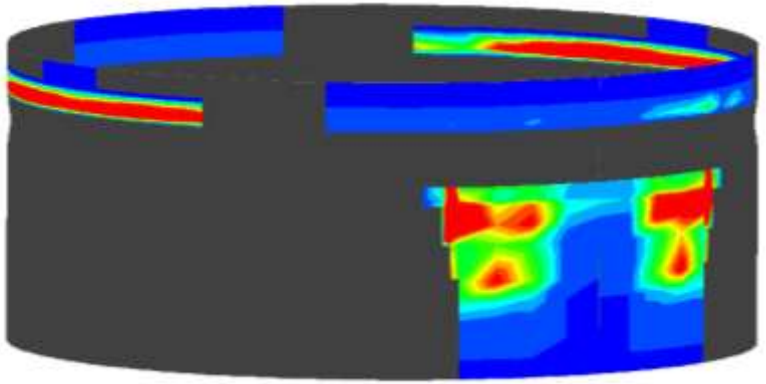


High Speed Case Study

- Predicted result shows asperity contact pressure at 15000 rev/min

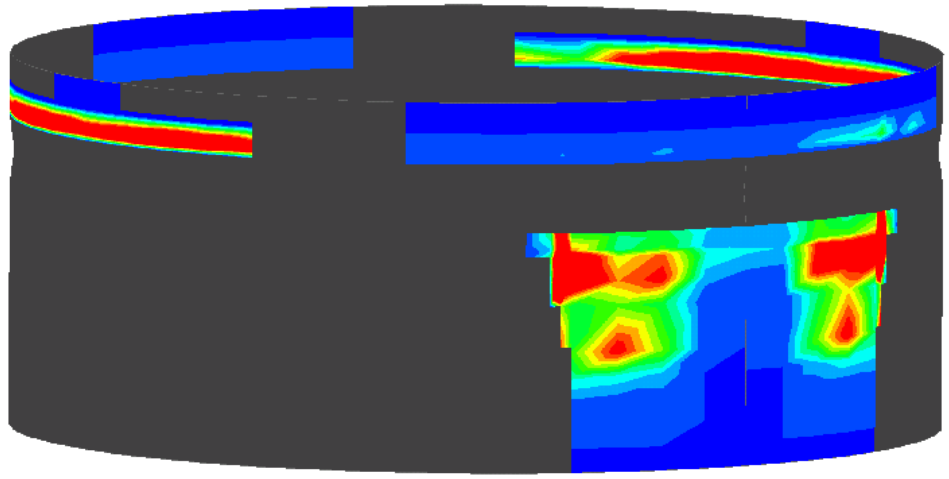
Wear region above rings

Each skirt has two patches of wear, either side of the central region
And
Centrally under the rings



Predicted Skirt Wear With Overheated Piston and Deformed Liner

- Predicted skirt to liner contact pressure with an over heated piston crown
- The regions of wear above the piston rings are now predicted

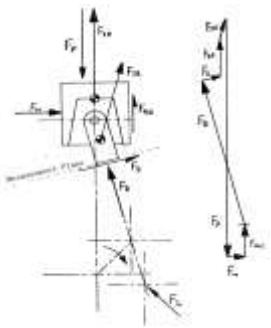


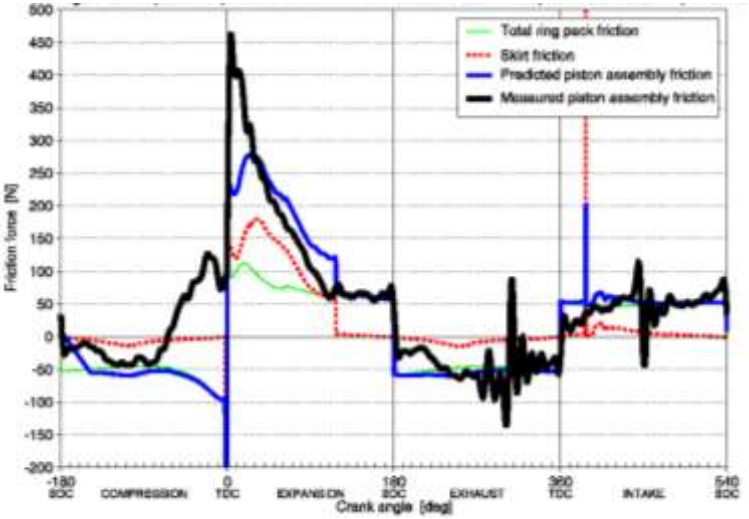
THRUST

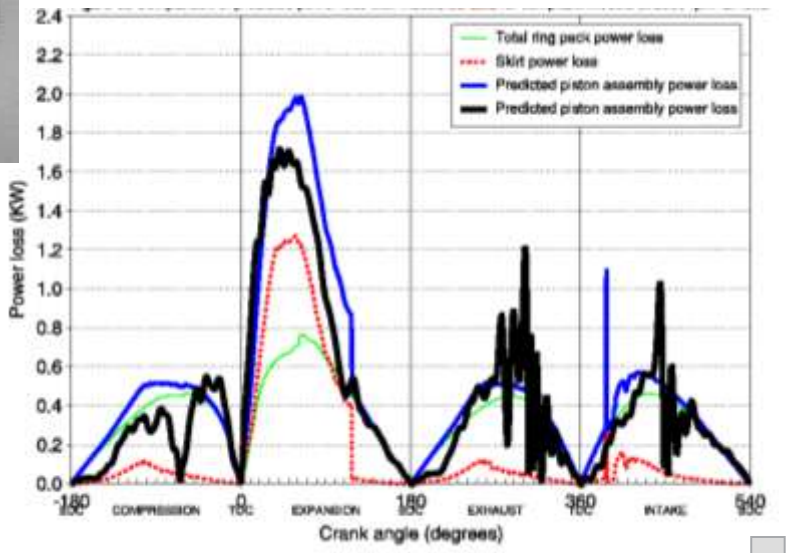
ANTI-THRUST

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
- Correlation between PISDYN simulation and test
- Trends observed in simulation supported by testing
- Simulation results makes it easier to understand and resolve wear and contact problems
- Reduction in costly testing
- Leads to lower product cost