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PISDYN

RINGPAK

Ricardo Software

Powertrain CAE Solutions

www.software.ricardo.com

What is PISDYN?

PISDYN is an advanced three-dimensional simulation package for predicting the dynamics of the piston and connecting rod assembly - enabling the optimization of the piston geometry and minimizing the need for expensive and difficult testing. Based around an advanced lubrication model for simulating the interface between the piston and liner, the engineer can use a hierarchy of structural models to minimize scuffing, wear, friction loss and piston slap.

Key product features

- Advanced EHL mass-conserving lubrication model for piston/liner interface
- Hydrodynamic and boundary lubrication models
- Single piece and articulated pistons
- Hierarchy of rigid, compliant and dynamic structural models
- Integrated FEARCE solver for FE matrix reduction

What is RINGPAK?

RINGPAK is an advanced two-dimensional simulation package for predicting ring pack dynamics, lubrication and gas flow for optimization of the ring pack. Based around advanced lubrication, gas and ring dynamic models, the engineer is able to reduce friction, wear, blowby and oil consumption, minimizing the need for expensive and difficult testing.

Key product features

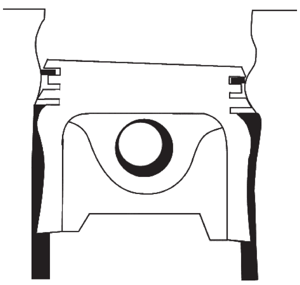
- Piston ring dynamics
- Gas dynamics model computes the mass flow of gas past each ring and inter-ring pressures
- Hydrodynamic and boundary lubrication models
- Advanced oil consumption calculations
- 3D effects including piston secondary motion from PISDYN and bore distortion from FEARCE

Piston dynamics

PISDYN calculates the secondary motions of the piston assembly by solving for the forces and moments of the piston/liner system and how these interact with the lubrication at the component interfaces throughout the engine cycle.

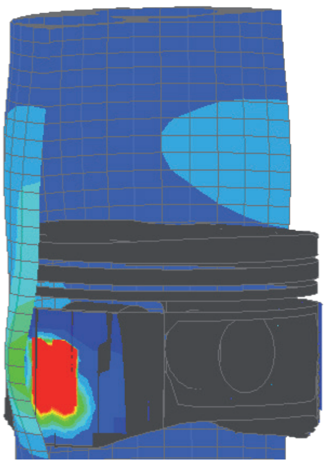
The lubrication model includes the effects of both hydrodynamic and boundary lubrication, as well as accounting for the elasticity of the piston skirt and cylinder liner.

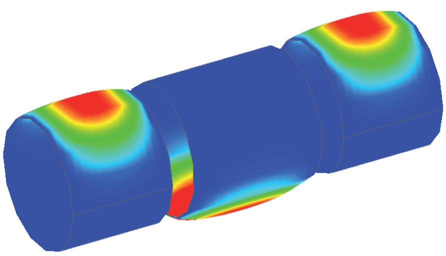
PISDYN also allows for a full hierarchy of solution levels ranging from rigid through compliant to fully dynamic components and from dry through partially flooded to full flooded oil supply zones.

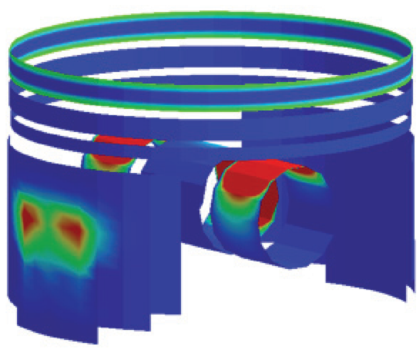


Capabilities

- Mass conserving Elastohydrodynamic Lubrication (EHL) model
- Boundary lubrication model
- Average flow model (flow coefficients)
- Dry, partially and fully flooded oil supply options
- Rigid, compliant and dynamic piston and liner model types
- Prediction of lubricated extend and cavitated regions
- Modelling lubricated, unlubricated zones and cut-outs
- Bore distortion and bore gas pressure deformation
- Piston skirt thermal, inertial and gas pressure deformation
- Piston crown lands, skirt and bore profiles
- Spatial varying viscosity
- Crown lands contact model
- Simplified top ring model
- Animated results on piston skirt, cylinder liner, wristpin bearings and crown lands
- Complete cycle results plot







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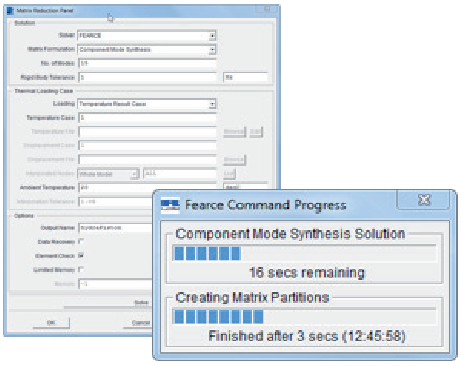
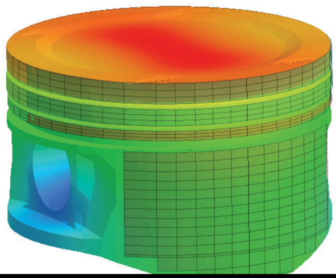
Finite Element (FE) modelling

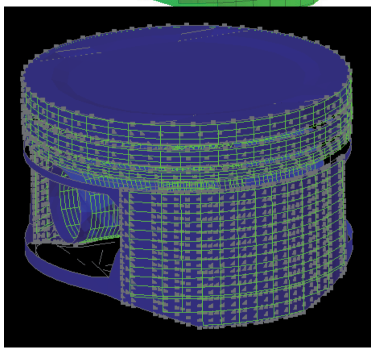


PISDYN incorporates an advanced interface that allows a user to utilize FE models to calculate the mass and stiffness metrics required for dynamic and compliant analyses, as well as deformations due to thermal, pressure and inertia loads. Any combination of model level can be chosen for either the piston or liner side assemblies.

With its internal FE solver, PISDYN has the capability of performing all of the required analyses, or if the user prefers, it can also set up appropriate analysis decks for the major third-party solvers, such as ABAQUS and NASTRAN.

Post solution, the PISDYN FE interface also has the capability of applying the calculated forces onto component FE models to provide boundary conditions for FE stress analyses.





Capabilities

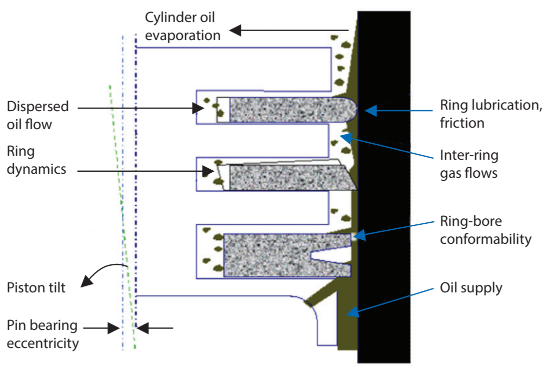
- Interactive 3D graphical user interface (RAPID GUI)
- Automatic selection of sets for loading
- Vectorized Sparse Solver (VSS) Static (Guyan) and dynamic (CMS) reduction
- Thermal, inertial and gas pressure deformations
- Temperature dependent material properties
- Complete piston and liner (or engine block) models with optional half model
- Inertia relief for static models
- Built-in translators from commercially available FE packages
- Pressure loading of cylinder head
- Back-substitution of results for complete piston/liner FE analyses
- Piston and liner dynamic models
  - 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 analysis for piston slap prediction

Ring dynamics

RINGPAK simulates the motion of each separate ring on the piston assembly based upon an axi-symmetric assumption. The ring motion is decomposed into twist, axial and radial motions. The effects of the surrounding gas pressure, boundary lubrication, hydrodynamic lubrication, system friction and inertia are taken into account in force and momentum balances.

Sealing calculations can be performed based on detailed gas flow analyses through the ring pack. From these studies, blowby and blow back values can be predicted. Using this methodology, RINGPAK forms an interconnected system of gas volumes. The gas flow between these volumes is controlled by either the ring motion or by the conformability of the rings to the liner body during deformation.

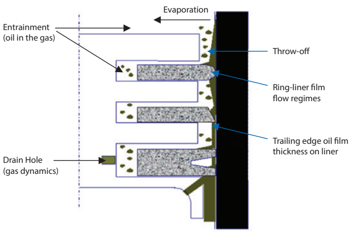
RINGPAK includes two flow models, one based on isentropic conditions and the other based on compressible isothermal flow. Each flow model can either be selected explicitly, or RINGPAK can be left to decide its solution method based on flow parameters.



Capabilities

- Axi-symmetric 2D treatment including 3D features for bore distortion, ring conformability, crown shape, and crown thermal distortion
- Mass conserving hydrodynamic lubrication model
- Boundary lubrication model
- Channel flow and orifice flow inter-ring gas dynamics
- Ring-liner conformability
- Different oil supply modes

Oil transport and consumption



RINGPAK's oil transport calculations utilize models for the two key effects known to act upon the system.

The ring/liner oil transport model simulates the oil scraping action of the piston rings. It includes the effects of areas of non-conformance, liner honing, ring-liner clearance, axial gas pressure differences and ring end gap size. Oil accumulation at the leading edges of the rings is also calculated.

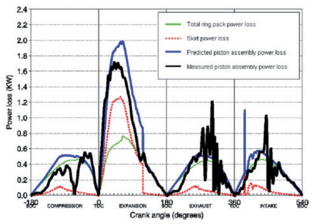
The oil sweep model simulates the oil transport along the crown surface. Oil attached to the crown surface is exposed to high forces due to piston acceleration and gas flow velocities. The solver analyses the effects of gas flow intensity, oil entrainment into flowing gas and oil accumulation on crown lands and grooves.

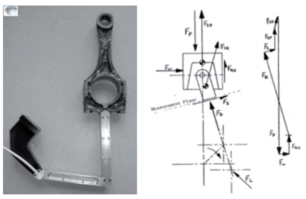
Results from the oil transport models are used in the determination of oil flooded areas where hydrodynamic pressure is developed.

Capabilities

- Oil transport modes
  - Ring/liner clearance
  - End gap
  - Liner hone
  - Ring non-conformance areas
- Types of Lubricant Oil Consumption (LOC)
  - Oil throw-off into combustion area
  - Oil entrainment of oil droplets into combustion area
  - Oil evaporation from liner surface exposed to hot cylinder gas

Case study 1: Friction





Objective

- Validation of the friction prediction capability of PISDYN and RINGPAK by comparing predictions with measured piston assembly friction force

Process

- Measurements were made on a single cylinder Ricardo Hydra gasoline engine using IMEP method
- PISDYN was used to predict friction force and power loss at the interface between the piston skirt and cylinder liner
- RINGPAK was used to predict the friction force and power loss at each ring
- Total friction force and power loss due to skirt and rings was compared with the measured data

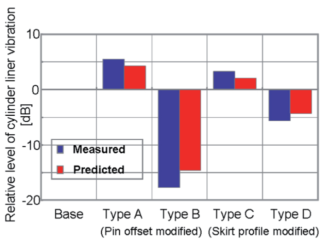
Parametric studies

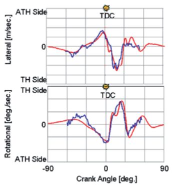
- Engine load
- Engine speed
- Skirt surface roughness
- Oil temperature
- Liner surface texture
- Boundary friction coefficient
- Oil grade

Result

- Graph shows good correlation between measured piston assembly friction power loss and sum of predicted values for rings and skirt

Case study 2: Noise and vibration





Objective

Validate the piston secondary motion, piston slap and liner vibration prediction capability of PISDYN by comparing predictions with experimental data

Model

- IL4 2.0 litre gasoline engine

Validated data

- Bore distortion
- Piston and cylinder block temperatures using VECTIS CHT analysis
- Cold idle transient warm up
- Cylinder block structural temperatures
- Piston secondary motion, lateral displacement and tilt liner acceleration

Parametric studies

- Piston pin offset
- Piston skirt profile

Result

- Graphs show good correlation between measured piston secondary motion and liner acceleration, and PISDYN predicted values

For further information about Ricardo Software products and services, contact us:

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