SIMPACK Engine

Content:

- Application Overview
- New SIMPACK Engine Modelling Elements
- SIMPACK Engine Database
- Product Outline
- Conclusion
SIMPACK Engine: Application Overview

Valve Train

Timing Mechanisms
Accessory Drive

Crank Train

'Upper' Engine Dynamics

'Lower' Engine Dynamics

SIMPACK User Meeting 04, SIMPACK Engine, 9th Nov. 2004, Marcus Schittenhelm
SIMPACK Engine: Application Overview

Analysis:

Valve Train
- valve longitudinal and lateral dynamics
- valve spring force/stress/durability
- contact forces
- camshaft torsional/bending behaviour
- camshaft bearing design
- ...

Timing Mechanisms
- chain dynamics (forces, vibrations, noise)
- belt dynamics (forces, vibrations, noise)
- gear dynamics (forces, displacements, …)
- timing mechanism torsional oscillations
- crankshaft/camshaft bending influence
- ...

Crank Train
- camshaft torsional/bending behaviour
- camshaft bearing design
- connecting rod bearing design
- flywheel design
- …
Analysis:

There are interactions between timing mechanism, ‘upper’ and ‘lower’ engine dynamics:

>> Complete System Behaviour!
Overview:

- Rigid Body Contact Elements
- Flexible Body Contact Elements
- Hydraulic Lash Adjuster
- Dynamic Valve Spring
- Hydrodynamic Bearings
- Combustion Gas Forces
- Gearwheel
- Chain
- New Time Excitations
- Order Analysis
Rigid Body Contact Elements:

- Contact Surface Description
  - *.su2 files
  - carthesian coordinates
  - **cylinder coordinates**
  - **advanced surface 2D plot**

- Moved Markers
  - 2D moved marker
  - 3D moved marker
  - 2D multi point contact

- Contact Force Law
  - constraint
  - single sided spring damper
  - **Hertzian contact**
  - Friction
Flexible Body Contact Elements:

- Elastic Moved Marker
  2D curve on 2D curve

- Elastic Moved Marker
  2D Curve on 3D Surface

- Direct (!) contact on flexible bodies

> no contact surface stiffening
  (as is common with former MBS methods)
Hydraulic Lash Adjuster:

- Detailed model based on
  - oil properties
  - geometric dimensions
  - spring parameters
  - check ball dynamics

- Equivalent model
  - without check ball dynamics
  - optimised calculation speed

- Can be used as
  - valve clearance adjuster (moved and fixed)
  - hydraulic chain tensioner
Dynamic Valve Spring:

- Two levels of model detail
  - 1D Multi Mass model
  - 3D flexible model (SIMBEAM based)

- Automated model generation process, based on physical and geometrical spring parameters:
Dynamic Valve Spring:

- Arbitrary user defined winding shapes

**cylinder**  |  **cone**  |  **beehive**  |  **barrel**  |  **...**
Dynamic Valve Spring:

- Arbitrary user defined winding shapes

- Cylinder
- Cone
- Beehive
- Barrel
Dynamic Valve Spring:

- Various types of cross section shapes. e.g.:

  - **cylinder:**

  ![Cylinder Diagram](image)

  - **poly arc:**

  ![Poly Arc Diagram](image)

  - **ellipse:**

  ![Ellipse Diagram](image)

  - **rectangle:**

  ![Rectangle Diagram](image)
Dynamic Valve Spring: 1D Multi Mass

- Arbitrary body/winding discretisation
- Arbitrary winding contact discretisation
- Can be use as standalone model (e.g. for determining force-displacement and frequency-displacement characteristics)
- Can be used as an interchangeable substructure within a main model

> Optimum calculation performance due to SIMPACK’s minimal equations of motion
Dynamic Valve Spring: 3D SIMBEAM

- Arbitrary beam/winding discretisation
- Arbitrary winding contact discretisation
- Can be use as standalone model (e.g. for determining force-displacement and frequency-displacement characteristics)
- Can be used as an interchangeable substructure within a main model

> Optimum level of accuracy combined with reasonable calculation speed
Hydrodynamic Bearings in SIMPACK by IST:

- Based on TOWER-MBS Software from IST in Aachen (theory of Prof. Knoll)

- Two levels of detail available in SMPACK at the moment:
  - Impedance method (look up table, fast)
  - Online FEM method (quasi static EHD)
  - Offline EHD (TOWER)

- Applicable with radial and axial hydrodynamic bearings, e.g.
  - crankshaft bearings
  - camshaft bearings
  - connecting rod bearings
  - valve guidance
  - ...

- Possible future development for SIMPACK:
  - ‘True’ Online EHD
Hydrodynamic Bearings in SIMPACK by IST:

<table>
<thead>
<tr>
<th>Impedanz Methode (Kennfeldlösung)</th>
<th>verfügbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Interpolation in Kennfeldern (sehr schnell)</td>
<td></td>
</tr>
<tr>
<td>- Eingeschränkte Modellbildung</td>
<td></td>
</tr>
<tr>
<td>(Nur Zylindrisch, keine Kippung, Nuten, ...)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Online FEM-Methode</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Lösung der Reynoldsgleichung in jedem Zeitschritt</td>
<td></td>
</tr>
<tr>
<td>- Beliebige Schalengeometrie (Ölnuten, Taschen, etc.)</td>
<td></td>
</tr>
<tr>
<td>- Variabler Spalt in Axialrichtung (Kippung)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Offline-EHD (TOWER)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Zapfenschiefstellung und Kraft über der Zeit (MKS)</td>
<td></td>
</tr>
<tr>
<td>- nachgeschaltete EHD-Analyse (rückwirkungsfrei)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Online-EHD</th>
<th>geplant</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Kompakte Einzelkörper (z.B. Pleuel)</td>
<td></td>
</tr>
<tr>
<td>- Hauptachsenreduktion für Bohrung</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Online-EHD mit Substrukturtechnik</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Komplexer Motorverbund mit $n$ Lagern</td>
<td></td>
</tr>
<tr>
<td>- Substrukturen mit Hauptachsenreduktion</td>
<td></td>
</tr>
<tr>
<td>- Interfacemoden mit SVD (Randmoden)</td>
<td></td>
</tr>
<tr>
<td>- hohe lokale Genauigkeit in jeder Lagerbohrung</td>
<td></td>
</tr>
</tbody>
</table>
Hydrodynamic Bearings by IST:
Radial Bearings

- Arbitrary bearing profiles:
  - segmentations
  - oil inlets
  - lateral offsets
  - lemon bore
  - ...
Hydrodynamic Bearings by IST:
Axial Bearings

- Detailed modelling of valve guide
- Online FEM method necessary
Combustion Gas Forces:

- piston forces due to gas pressure array
- arbitrary engine types
- static and dynamic array shifts

Applications:

> crankshaft bearing design (loads)
> engine torsional excitations
SIMPACK Gearwheel:

- Involute spur and helical gears
- Internal and external gears
- Backlash and friction
- Single and multi-point contact
- Variable separation distance of gear wheels
- Addendum and dedendum modification
- Force element parameterisation via SIMPACK 3D gearwheel primitive
- Contact force visualisation
SIMPACK Engine: Single Modelling Components

SIMPACK Chain*: 

Components: 
- roller + bush chain 
- sprocket wheels (ISO 606) 
- guides 

Dynamic effects: 
- polygonal effects 
- torsional impact (during running-in and -out) 
- drive and brake moments 
- elongation 
- centrifugal force 
- clearance 
- ...

*) available as SIMPACK pre release on request
SIMPACK Chain*:

Modelling Capabilities:

- elastic chain-sprocket contact
- elastic chain-guide contact
- elastic link joint contact
- coulomb or viscous friction
- clearance
- easy to use automatic chain trajectory setup
- detailed hydraulic chain tensioner
- ...

*) available as SIMPACK pre release on request

Pictures according to:
SIMPACK Chain*:

SIMPACK highlights:
- Optimised ‘macro‘ chain force element
- SIMPACK’s renowned relative coordinate algorithm, optimised for chain application
- SIMPACK’s renowned and proved integrator (no numerical damping (!))

> **Highest simulation performance and accuracy**

*) available as SIMPACK pre release on request
SIMPACK Chain*: 

Ongoing development:

- advanced model setup GUI
- silent chain
- flexible guides
- arbitrary sprocket profiles
- ...
New Time Excitations:

- constant value (selectable as position, velocity or acceleration)
- linear state transition (selectable as position, velocity or acceleration)
Order Analysis:

- amplitude or effective value
- variable hanning window settings

Input:
- crankshaft rotational signal
- arbitrary signal to be analysed

Output:
- response signal for selected engine order

> Engine vibration analysis
SIMPACK ENGINE Database

Database of ready-to-use parameterised models, e.g. **Valve Train**
SIMPACK ENGINE Database

Database of ready-to-use parameterised models, e.g. 
**Crank Train**
SIMPACK ENGINE Database

Easy, fast and reliable **Entire Engine** model setup using SIMPACK’s database concept which includes substructures:
SIMPACK ENGINE:

**BASIC**
- Rigid Contact
- Dyn. Valvespring (Multimass)
- Hydraulic Lash Adjuster
  ...

**ADVANCED***
- Flex. Contact
- Dyn. Valvespring (SIMBEAM)
- FEMBS
- Flex. Valveshaft (SIMBEAM)
  ...

- (E)HD (Impedanz Meth.)
- Gas Force
- FEMBS
  ...

- (E)HD (Online FEM Meth.)
  ...

**Valve Train**

**Crank Train**

**Gear Wheel**

**Chain**

**Timing Belt**

**Accessory Belt**

*) includes BASIC functionality
SIMPACK ENGINE:

- Product suite used for multi-body simulation of crank train, valve train and timing mechanisms
- Basic and Advanced versions
- Database of ready-to-use parameterised models and substructures (easy and comfortable entire engine setup and analysis)
- Fully integrated in standard SIMPACK environment
- Fully compatible with any other SIMPACK product