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New SIMPACK CHAIN Module

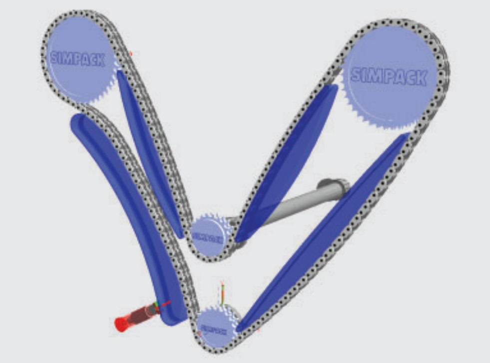

Figure 1

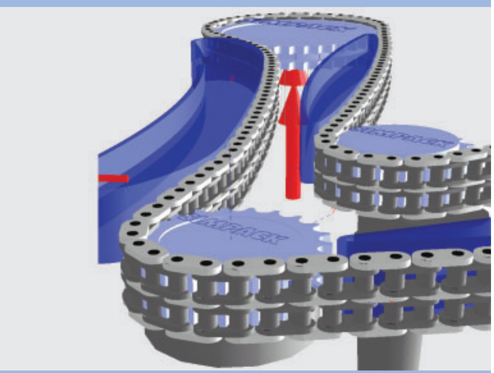

Figure 2

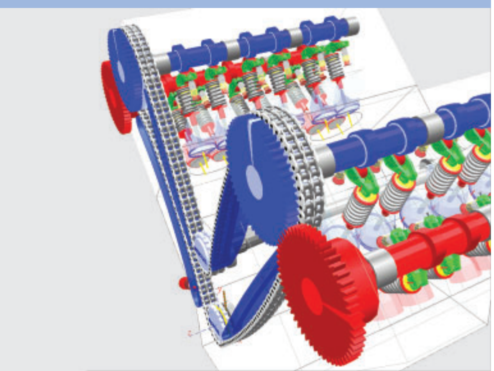

Figure 3

With SIMPACK Version 8.709, the first official release of a new high end chain simulation module has been made available. The CHAIN module uses SIMPACK's well known and verified relative co-ordinate algorithm, together with several completely new approaches. This has brought impressive calculation performance and result accuracy both with stand-alone chain models (Figure 1-2) and highly detailed complete engine models (Figure 3).

It is well known that specialised simulation tools have been available for the accurate and calculation efficient modelling of highly detailed chain systems. The SIMPACK CHAIN module offers, for the first time, comparable performance in a general multibody simulation program. This has been made possible due to the relative co-ordinates algorithm in SIMPACK, which is fully exploited and has been enhanced for the calculation of chain systems. In addition, the available calculation methods in SIMPACK have been optimised and combined for chain systems – hybrid solver using explicit and implicit techniques. A particularly important feature, as always in SIMPACK, is the avoidance of using solver 'black box' settings (e.g. numerical damping) and ensuring that the solver is numerically stabile. These features have made it possible for SIMPACK to simulate detailed chain systems with the accuracy achieved by the 'best in class' chain specialised tools. This module has been seamlessly incorporated into the standard SIMPACK architecture. Individual chain models can therefore be easily changed and extended, and using the SIMPACK 'Substructures', can be integrated into entire engine models.

MODEL APPROACH AND INCLUDED EFFECTS

The important features of the new SIMPACK chain module include a highly developed pre-processing to ensure the optimised generation of the equations of motion and specialised GUI for the definition of the chain parameters and initial conditions. In addition the optimised calculation of the complex contacts are performed via a 'multi-force' Force Element.

The first release of the chain module offers the following functionality:

- Roller and bushed roller chains (figure 4)
- Chain wheels with the geometry definition according to DIN 8196 (figure 7)
- Rigid tensioner guides with the profile defined via arcs
- Generation of chain links as MBS elements with either 2 or 3 degrees of freedom
- Contact, clearance and friction between the chain links
- Contact and friction between the links and guides
- Contact and friction between the wheels and guides
- Detailed chain tensioner model, described via geometry and oil and mass characteristics with consideration of the plunger and valve-ball dynamics (figure 5)
- Chain post-processing output values

These features are important so that certain effects can be simulated:

- Polygon effect (figure 6)
- Changes in the link longitudinal velocity
- Changes in the link lateral velocity
- wheel run-in collisions
- Rotational collisions by wheel run-in and run-out
- Centrifugal forces
- Input and output torques
- Elongation

The following features are currently under development and shortly to be available:

- Toothed chains
- Flexible tensioner guides, generated in SIMBEAM or imported from complex FE models, which allow the contact force to be applied into the flexible body – similar to the SIMPACK flexible contact

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- unround chain wheels

MODEL GENERATION AND OPERATION IN SIMPACK

The interactive assembly and generation of the chain is performed using a specially developed graphical interface (figure 9). The sequence in which the chain is to run over the wheels and guides is entered. The ideal chain path is then automatically calculated from the entered chain components, including the link geometry and, if desired, an applied pre-loading of the chain. The chain links can then be automatically generated and positioned with the help of the idealised chain path and assigned their respective initial conditions. This ensures that the use of relative co-ordinates is optimised, as well as allowing the initial conditions to be easily and efficiently defined. When the solver is then started the chain steady state is quickly achieved.

The generated chain model can be used as a stand-alone chain simulation model. In addition measured crankshaft rotational eccentricities and camshaft fluctuating moments can be applied as boundary conditions to the chain. If this modelling does not provide the required accuracy then the interaction of the chain with valve- and crank-gear can be considered by loading the chain into an entire engine model. This can be easily performed by loading the chain as a SIMPACK 'Substructure'. Even these highly detailed and complex engine models can be solved due to the SIMPACK relative co-ordinates algorithm and through the development of the specialised chain numerics (hybrid solver). This results in excellent calculation performance in both efficiency and accuracy.

The following model describes how the SIMPACK chain module has been verified and gives an insight into how well the solver performs.

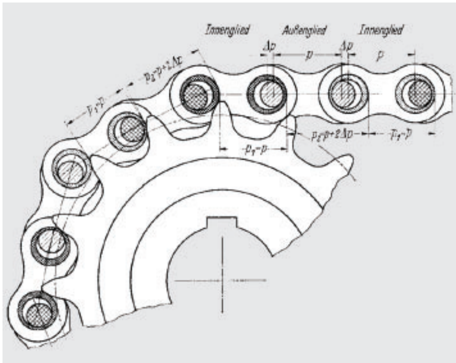

Figure 4

Figure 7

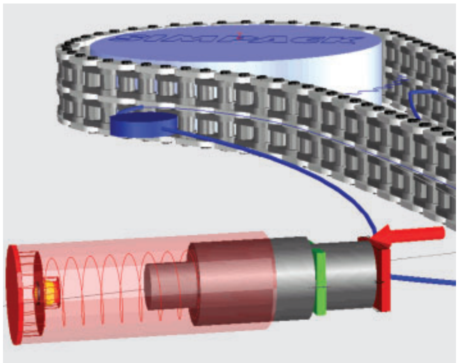

Figure 5

Figure 8

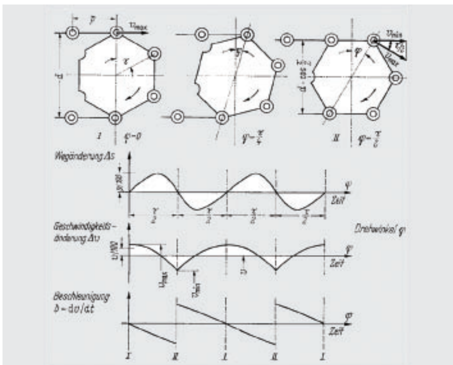

Figure 6

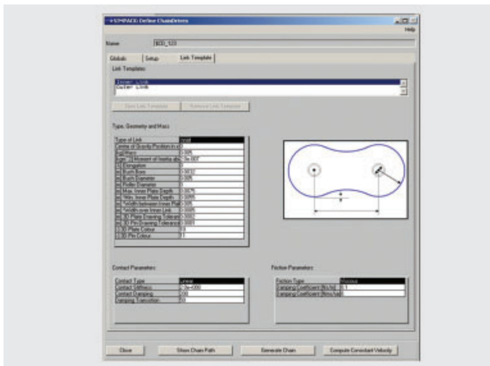

Figure 9

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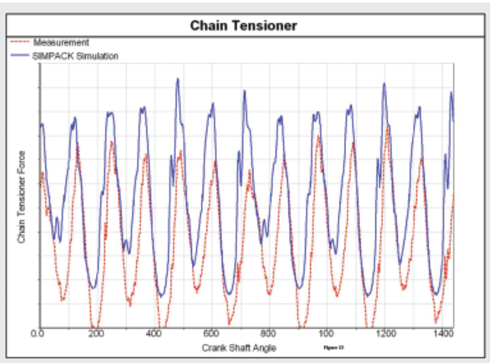

Figure 10

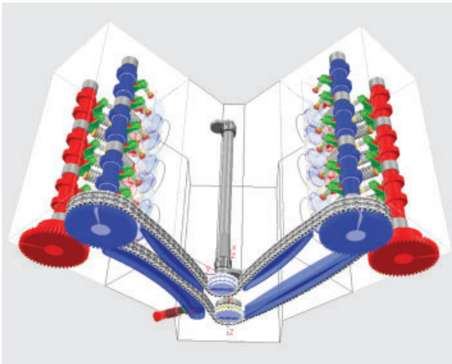

Figure 13

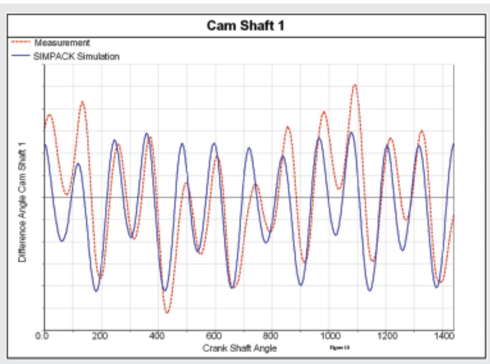

Figure 11

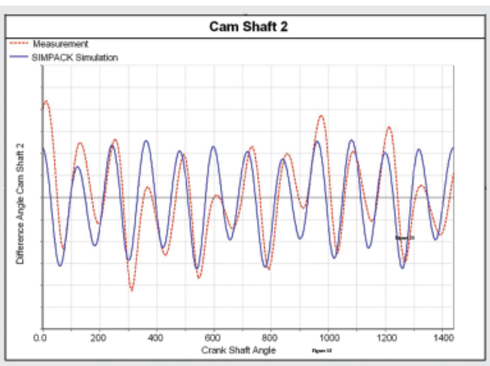

Figure 12

OEM VERIFICATION MODEL

The chain simulation verification model (figure 13) is an entire engine model offering complete interaction of the chain with the valve train. The model contains the following components:

- 29 flexible Bodies
- Approximately 1550 rigid Bodies
- Approximately 3400 states
- Chain with 3 degrees of freedom per link
- 24 detailed hydraulic lash adjusters with ball dynamics
- Detailed chain tensioner with ball dynamics
- Hydrodynamic bearings on the balancer shafts and camshafts

The calculation time required for this model to reach a steady state for a certain rotation speed is in the region of a few hours. The respective chain model on its own is solved in the region of a several minutes to a couple of hours. All the models were calculated on standard single processor PC's. Further calculation time improvements are currently being worked upon at INTEC and tested on this verification model. In the development of the chain module calculation speed is not the only consideration, but a great deal of importance is ensuring that the results are accurate. The very good correlation of the simulation results with the measured data shows how accurate the CHAIN module is. The correlation of the data is shown in the figures 10-12.