SimpackNews

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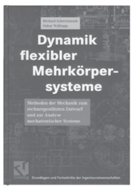
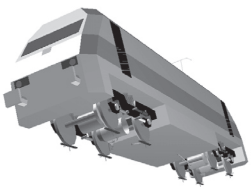
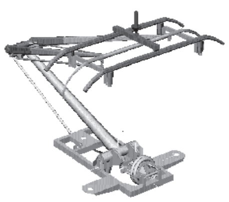
More Development Power than Ever for SIMPACK

The DLR (German Aerospace Center), which is responsible for the development of SIMPACK, has recently extended its range of activities to include the field of ground transportation. This has led to a significant improvement in quality and extent of the development resources for SIMPACK, which will in turn result in further technological advances and major enhancements of the Automotive+ and Wheel/Rail modules.







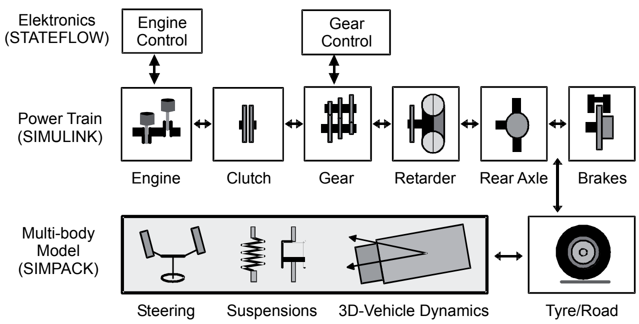
The main focus of the new area is aimed at technologies in which DLR experience and expertise derived from aerospace research can be cross-matched with ground transportation applications, especially in areas where the DLR has a leading scientific and technological position - for example mechatronic simulation. The research area will commence with a three-year period of intensive support after which this research will be integrated into the normal routine of DLR activities, as in the case of the aerospace program - demonstrating a determination and long-term commitment. Existing relationships and cooperations with other industrial sectors and research centers, including universities, will be consolidated and intensified (creating "networks" of cooperation). The establishment of the new focus on transportation technology will be combined with the further development of CAE technology for virtual prototyping and the development of mechatronic systems. The SIMPACK development team is to be significantly strengthened to enable this exciting new challenge to be met and initiated. The on-going development of efficient and effective mathematical solvers for non-linear kinematics, 3D-graphics, contact models, combined mechanical and control system tools and interfaces from multi-body simulation tools to any CAE techniques will be an area of intensive efforts. New resources for the further refinement of the Automotive+ and Wheel/Rail modules will be created - strengthening the existing manpower.

The development of SIMPACK's automotive and railway modules will be continued with the cooperation of industrial partners, thereby guaranteeing the quality and efficiency of current software and the future investment in the software of tomorrow. The DLR would like to ask partners and SIMPACK users from the automotive and railway industries as well as from research centers to make contact and to share their ideas on which direction and approach the new development should take.

Gerd Baumann, Michael Grimm, Jens Neubeck
FKFS Stuttgart

Realtime Simulations With SIMPACK

A procedure to incorporate SIMPACK multi-body models into the software tool SIMULINK for real time calculations has been developed at FKFS, the Research Institute of Automotive Engineering and Vehicle Engines Stuttgart, in cooperation with INTEC. Such type of calculations is very common in the automotive industry, where it is part of the design process of suspension systems, vehicle dynamics and complete power trains. This newly developed procedure, however, is not restricted to these types of systems but enables the real time simulation of general mechanical systems as well as mechatronic systems.



Application Domain

Real time simulation is generally regarded as a vital part in the development of mechatronic systems. Especially in the automotive industry hardware-in-the-loop-simulators as test and development facilities are essential. Also driving simulators require real time motor vehicle models for demonstration and training purposes. SIMPACK is often used by FKFS for creating simulation models of motor vehicles in case the multi-body approach is suitable for a certain problem. This applies in general for the simulation of the handling performance of a vehicle, since the modelling of the interaction between the suspension and the chassis has proved to be successful using rigid and elastic bodies interconnected by joints. Force elements act between those bodies to represent components like springs, dampers, stabilisers and rubber elements. SIMPACK contains a large library of force-elements and additionally offers a user-routine interface which has been applied to write user force elements in FORTRAN code for active suspension elements. Summarising SIMPACK offers a universal tool for simulation of general mechanical systems and motor vehicles. Detailed models of complete motor vehicles, however, often require additional elements than traditionally used in multi-body simulation. Hydraulic and pneumatic components for instance are required for the accurate modelling of braking and steering systems. Furthermore it is desirable to model electronic control devices that can be simulated efficiently with so-called CACE software tools. The software tool SIMULINK with its module STATEFLOW is especially suitable for the modelling of these reactive systems and control loops. The creation of these detailed and advanced motor vehicle models is now attainable by using the specially designed interface between SIMPACK and SIMULINK. By combining these two powerful simulation tools an advanced modelling technique has been made available which even allows real time modelling. The figure aside shows a complete real time model that contains elements from a SIMULINK library created by FKFS consisting of a large number of power train components. The electronic control units of the engine and the gearbox are implemented within STATEFLOW. The dynamic model of the vehicle including the suspension and the steering system is contained within the MBS model created in SIMPACK and linked to SIMULINK. The tyre is modelled within SIMULINK using a special algorithm suitable for real time simulations. Extensive tests on the FKFS driving simulator demonstrate the efficiency of the interface for real time applications (see figure aside). The described vehicle model proves to be stable under all load case scenarios. This also holds true for situations where skid or wheel lift occurs.

Coupling of SIMPACK and SIMULINK for Real Time Applications

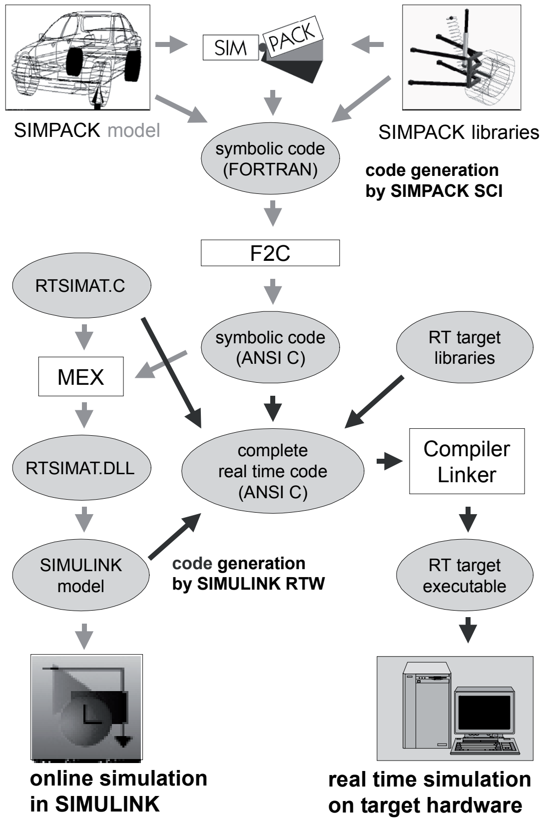
SIMPACK and SIMULINK are both simulation tools that contain efficient code generators and enable an almost fully automated implementation of combined models on real time computers. The figure aside gives a schematic representation of the real time coupling of SIMPACK and SIMULINK. The SIMPACK-code generator (Symbolic Code Interface) creates FORTRAN code that represents the MBS model. A conversion program F2C converts the FORTRAN code to ANSI-C code. This code is linked to the SIMULINK model through a function called RTSIMAT – a component of the general interface SIMAT, which was originally not suitable for real time applications, but has been modified by FKFS. The SIMPACK model emerges within SIMULINK as an S-Function-Block with in- and outputs that correspond with in- and output vectors defined in the SIMPACK model. The online simulation can now be performed from within SIMULINK using any integration procedure for ordinary differential equations available within SIMULINK. In an additional step the SIMULINK code generator (Real Time Workshop) creates C code that can be implemented for real time simulations on all the platforms that are supported by SIMULINK Real Time Workshop. At FKFS combined SIMPACK/SIMULINK models were tested on an Industry-PC (Software: MathWorks xPC-Target), a Standard-PC (MathWorks RT Windows Target), a DSPACE DSP/alpha-System (DSPACE RTI) and a Power-PC (Lynx OS). To extend this option to further platforms will require little effort.

Force Elements in SIMULINK

As mentioned earlier force elements can be chosen from the standard SIMPACK library or imported via the user routine interface. But there is also a third option: force elements that interact with the MBS model can be modelled in SIMULINK. Sensors defined in SIMPACK provide measurements (displacement, velocity, and acceleration) that can be used as inputs to the force element model in SIMULINK. The calculated forces and moments can be fed back into the SIMPACK model, where they act at certain markers. The already mentioned tyre model is an example of such a force element.

Development

The interface is currently being developed and further improved by INTEC, DLR and FKFS. A new objective is to 'dissolve' the constraints in SIMPACK models. This will enable models that contain kinematically closed loops to be used with real time calculations. Furthermore a link between SIMPACK and ASCET-SD is planned, as this tool has become more and more popular in software development for ECUs in motor vehicles. The combination of ASCET-SD Prototyping Systems, SIMULINK/STATEFLOW and SIMPACK will provide a new opportunity to test control functions in a closed control loop in real time.



The FKFS Driving Simualator

Dr. Lutz Mauer
INTEC GmbH

Mehrkörpersysteme mit flexiblen Körpern

Sollen bei der Dynamikberechnung flexibler Strukturen sowohl die Vorteile der MKS- als auch der FEM-Berechnung genutzt werden, bietet sich die Einbindung flexibler Körper in die MKS-Berechnung an, wobei durch die Einführung von Modalkoordinaten den großen, nichtlinearen Starrkörperbewegungen die kleinen, weitgehendst linear beschreibbaren Deformationen der elastischen Verzerrungen überlagert werden. Die Autoren Richard Schwertassek und Oskar Wallrapp des neu erschienenen Buches Dynamik flexibler Mehrkörpersysteme haben es sich zur Aufgabe gestellt, eine möglichst vollständige Einführung in die theoretischen Grundlagen dieses Verfahrens zu geben.

Beide Autoren haben sich bereits mit der Entwicklung von Mehrkörper-Simulationsprogrammen (MULTIBODY, MEDYNA) und der Beschreibung elastischer Körper auf internationaler Forschungsebene einen Namen gemacht. Die objektorientierte Beschreibung standardmäßig benötigter Daten flexibler Körper im sog. Standard Data Input Datensatz, wie sie in den Mehrkörperprogrammen NEWEUL und SIMPACK verwendet werden, wurde von Oskar Wallrapp entwickelt.

Das Buch Dynamik flexibler Mehrkörpersysteme bleibt an keiner Stelle an der Oberfläche der Problemstellungen hängen. Bereits in der Einleitung zeigt die umfassende Darstellung der neueren Entwicklungen in der Mehrkörperdynamik die Kompetenz der Autoren. Im zweiten Kapitel werden, wie in einem Lehrbuch, die Grundlagen der linearen und nichtlinearen Elastizitätstheorie systematisch auf über 60 Seiten dargelegt.

Das dritte Kapitel ist den Prinzipen der Mechanik gewidmet, die zur Formulierung der Bewegungsgleichung von MKS-Systemen Anwendung finden. Dabei werden die Differentialprinzipe und das Integralprinzip auf die Bewegungsgleichungen von Kontinua mit inneren und äußeren Bindungen angewandt.

Das vierte Kapitel beschäftigt sich mit der mathematischen Modellierung von Balken als elastisches Kontinuum, wobei jene Effekte berücksichtigt werden, die sich aus einem beschleunigt bewegten Bezugssystem (z.B. Erhöhung der Steifigkeit infolge von Zentrifugalkräften) und aus nominellen äußeren Lasten (geometrische Steifigkeiten aus Gleichgewichtsbedingungen am verformten Balken) ergeben.

Nach all den theoretischen Vorarbeiten beginnt im sechsten Kapitel die eigentliche Themenstellung des Buches, nämlich die Mehrkörpersysteme. In einigen hundert Formeln wird nochmals ein mathematisches Feuerwerk zur Aufführung gebracht, das den Stand der Forschung auf dem Gebiet der Dynamik flexibler Mehrkörpersysteme darlegt. Abrupt endet der Hauptteil des Buchs mit der MKS-Analyse eines Schubkurbelgetriebes mit flexibler Kurbel- und Koppelstange. Wohl ein Zeichen dafür, daß sich die beiden Forscher noch einiges vorgenommen haben, bevor sie den Zeitpunkt sehen, ein endgültiges Schlußwort zu schreiben, mit dem der Abschluß der Forschungsarbeiten zum Thema der flexiblen Mehrkörpersysteme zum Ausdruck gebracht werden kann. Also blättert man zurück und läßt sich Vorwort

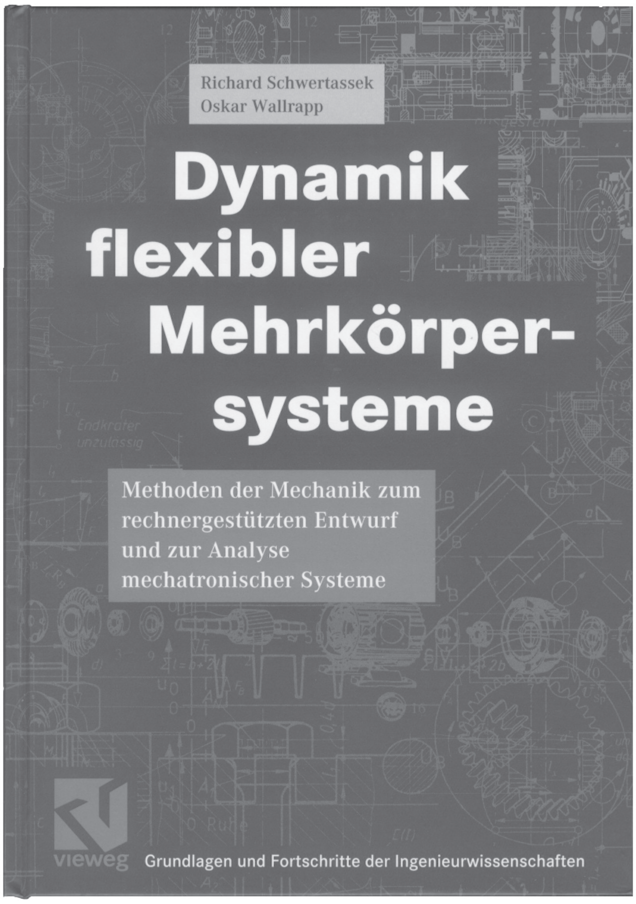
The book wich is the subject of this review is published in German. Please contact INTEC for further information about flexible multi-body systems.

und Einleitung nochmals auf der Zunge zergehen. Das Schlußwort wird wohl einer englischsprachigen Publikation vorbehalten sein. Zu Kapitel 6 gehört auch die Definition des den SIMPACK-Anwendern wohlbekannten objektorientierten Datensatzes Standard Input Data (SID-File) zur standardisierten Beschreibung flexibler Körper innerhalb eines Mehrkörpersystems. Für die im Buch durchgearbeiteten Beispiele elastischer Balken und Balkenstrukturen wird die Bestimmung der Matrizen der einzelnen Datenobjekte erläutert.

Im Anhang werden die verwendeten Symbole und Bezeichnungsregeln sowie die Grundregeln der Vektorrechnung und des Rechnens mit den korrespondierenden Koordinaten eingeführt. Das Literaturverzeichnis beinhaltet sowohl die wesentlichen Werke zur Darlegung der Grundlagen der Mechanik als auch alle relevanten Arbeiten auf dem Forschungsgebiet der flexiblen Mehrkörpersysteme. Ein ausführliches Sachwortverzeichnis mit etwa 450 Begriffen rundet das Werk ab. Es ist eine wertvolle Hilfe, so daß dieses Buch schon fast als Nachschlagewerk für den MKS-Anwender angesehen werden kann.

Durch die Kapitel 4 bis 6 ziehen sich die durchgerechneten Beispiele eines geraden Balkens und einer Balkenstruktur, so daß dem Leser die Probleme der Diskretisierung und der Wahl der Ansatzfunktionen verdeutlicht werden. Die in den Kapiteln 5 und 6 präsentierten Beispiele können zur Vertiefung des Verständnisses mit Mathematica nachvollzogen werden. Die zugehörigen Datenfiles sind im Internet unter http://www.vieweg.de/downloads zum Download bereitgestellt. Das Buch kann unter der Homepage des Buchverlags direkt bestellt werden.

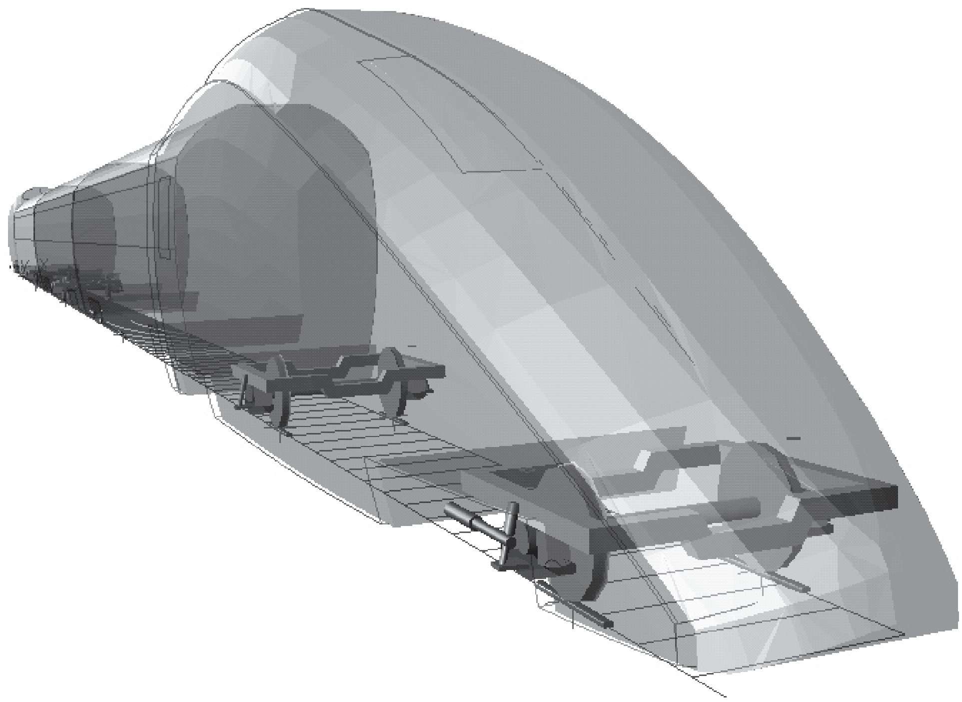
Studenten und Ingenieure, die sich mit der Simulation von Mehrkörpersystemen befassen, ist dieses Buch eine wertvolle Hilfe, sofern die Bereitschaft gegeben ist, tiefer in die Materie einzusteigen. Für den Ingenieur, der die Simulation der Dynamik flexibler Mehrkörpersysteme nicht nur als Black-Box Problem betrachten will, ist dieses Buch ein absolutes Muß. Das Buch nimmt in seiner Allgemeinheit nur in wenigen Absätzen direkten Bezug auf SIMPACK, dennoch sind wesentliche Teile im Umfeld von SIMPACK entstanden, wobei die mit Mathematica durchgerechneten Aufgabenstellungen als Referenzbeispiele zur Verifikation der programmtech-nischen Umsetzung in SIMPACK angesehen werden können.



Andreas Böttcher
INTEC GmbH

Modular Train-Models Using Substructures

Modern trains for city and local transport are constructed as a combination of sub-components to create an optimal configuration for different scenarios. Tailor-made vehicles are required for specific applications and track conditions. However, the price and design efforts have to be kept to a minimum. This is were SIMPACK's database concept offers a distinct advantage for users in a highly competitive industry. SIMPACK offers new methods to minimise the planning and interpretation effort that is required for modelling vehicles with a large range of variations.



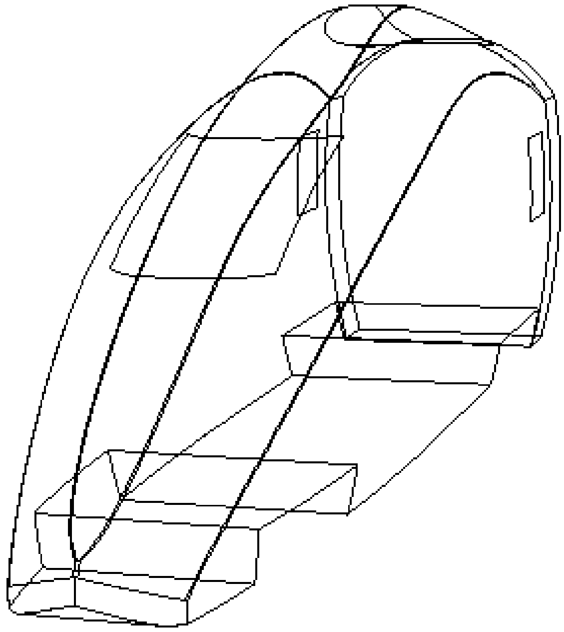
The vehicle dynamics depend largely on the global vehicle concept and its major components as determined during an early stage in the design process. However, when for example ride comfort and handling have to be optimised, minor details and components can have a very significant influence. Therefore simulation models must be easily adaptable to various global vehicle configurations whilst reflecting on detailed changes to minor components. The use of modular concepts increases the complexity of simulation models. To cover all the detailed variations in vehicle configurations requires a much larger computational effort than a fixed configuration would. Therefore an intelligent approach to data handling and collection is needed.

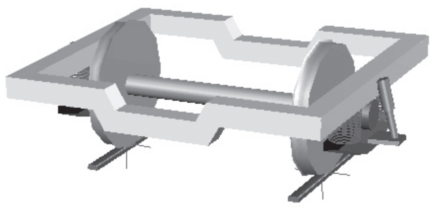
Substructures

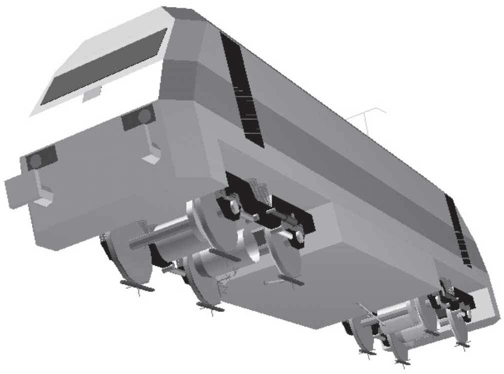
Models of bogies for instance can be saved as substructures within SIMPACK and can be used within several complete vehicle models simultaneously. Changes made to the substructures will reflect on all the main models that use that particular substructure. This is an fully integrated feature of SIMPACK. The user can decide whether a model should be further subdivided into functional elements (wheelset, bogie, vehicle body, etc.) and model specific elements or perhaps into standard components and project specific components that need to be optimised. An important characteristic of the SIMPACK database concept is its wide range. Almost every modelling element that can be used within SIMPACK can be added to the database. Substructures used in Wheel/Rail models are completely self-sufficient SIMPACK models and are fully compatible with all the standard elements from a general multi-body system. Not only is it possible to use a complete bogie in several vehicle models, but every detail like a car body element, an airspring, a bump stop, a drive train or an anti roll bar can be treated as an independent user specific substructure. This concept provides an ideal tool for building a company specific simulation environment.

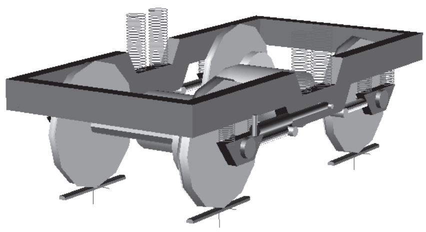
Data Base Projects

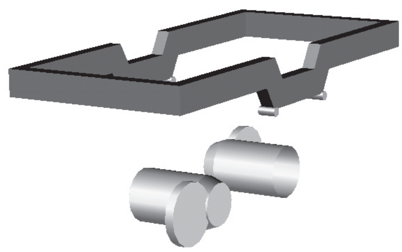
As an example, one or more wheelsets and the bogie frame can be modelled as a single substructure. The advantages of the SIMPACK database become apparent when one wishes to model several different versions of this bogie, choosing for example either steel springs or airsprings. The different levels within the SIMPACK database allow the user to select precisely those modelling elements that have to be used within a specific model. Another substructure for instance contains sub-models of either steel springs or airsprings that act between two so-called dummy bodies. The main model contains a link to either the steel spring or airspring sub-model, depending on which is currently required. The dummy bodies of the sub-model are linked to bodies in the main model by zero degree of freedom joints. This type of joint is fully integrated into SIMPACK, which means that adding a zero degree of freedom joint to a model will not increase the required computational effort.
A further example is the use of lateral bump stops in trams to limit the lateral movement. Bump stops with a small clearance usually reduce the ride comfort. However the amount of clearance that is allowed is often limited because the space available to the train is often reduced by features like tunnels, signs and platforms - typical quantities that differ from one customer to the other. The same bump stop can be modelled as separate substructures with different levels of detail. One substructure might be modelled as a force element with a specific force-displacement curve while another substructure consists of a three dimensional contact model between arbitrarily shaped bodies. The first bump stop model can be used for ride comfort calculations, while the second is used for a detailed calculation of the bump stop dimensions and shape to satisfy any space requirements - based on one and the same vehicle model.
So the database concept can not only be used to model separate types of vehicle configurations but also to select different types of models for different types of calculation. If one suspects that the configuration of the drive line will influence the ride through a twisted track, extra substructures that model these elements can be added with just a few mouse clicks, while these elements are omitted for other types of calculations.
Experience has shown that creating a sub-structured model will not require much more effort than creating a model in conventional technique. Concentrating on modelling small substructures and analysing these substructures separately before using them in the main models actually offers distinct advantages that compensate for the effort required for effectively organising the database. Different simulation scenarios complete with totally different vehicle configuration can be modelled efficiently and quickly once a database is completed.
The flexibility offered by SIMPACK

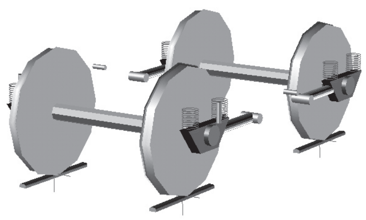












that users are accustomed to remains fully intact when applying the database concept. Almost any parameter that is defined within a substructure can be overwritten and saved locally in the main model. It is also possible to update the complete model by setting the global vehicle parameters like track gauge and rail profiles in the main model.
The SIMPACK database concept in combination with SIMPACK Wheel/Rail provides a modelling technique that truly supports the modular structure of real train vehicle design.

Ready to Use Models

SIMPACK Wheel/Rail is designed for optimum flexibility to support any leading edge technological solution for modern railway systems. However, the user can also access a broad range of standard models provided by the Wheel/Rail database. Parameterised models of a two axle bogie for passenger cars, a freight train bogie and a single axis bogie are available, as well as the according complete vehicle models that take full advantage of the described database features. These models can be used by adapting their design parameters or can be modified at one's discretion and thereby serve as starting point for the creation of a company specific data base.

Summary

Which are the major advantages in applying the SIMPACK database concepts to modular train vehicle design? First of all it is important to realise that SIMPACK Wheel/Rail is not a stand-alone product, but is seemlessly integrated into SIMPACK and its wide range of modelling and analysis tools. SIMPACK models of train vehicles are regular multi-body models supplemented by additional elements to model the contact between wheel and rail. This enables the realisation of innovative solutions for train vehicles from kinematic wheel guiding to active suspension systems, without any limitations which might arise from predefined models. The database fully supports the adaptation of SIMPACK Wheel/Rail to company specific and customer specific requirements as well as to user's specific working style.
Worried about the reliability of the described extensive functionality? SIMPACK Wheel/Rail has been in use in industry and universities for five years and has become the world wide market leader for multi-body simulation in the railway sector. SIMPACK Wheel/Rail has been successfully used for the design of more than fifty different railway vehicles. Furthermore, the continuous further development of SIMPACK is aimed at satisfying all the users wishes and demands.

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CAE Design of Controlled Pantographs

For high speed trains currently under development, satisfactory power collection by conventional pantograph/catenary systems arrives at its limits. Therefore, in a research project of Deutsche Bahn AG and DLR, a concept for an environment had to be set up to develop new or enhanced pantograph systems by using all required computer aided design (CAE) facilities. Additionally, the potential to improve the present systems of the DSA 350 series used in the German ICE trains by replacing purely mechanical by mechatronic components was investigated.

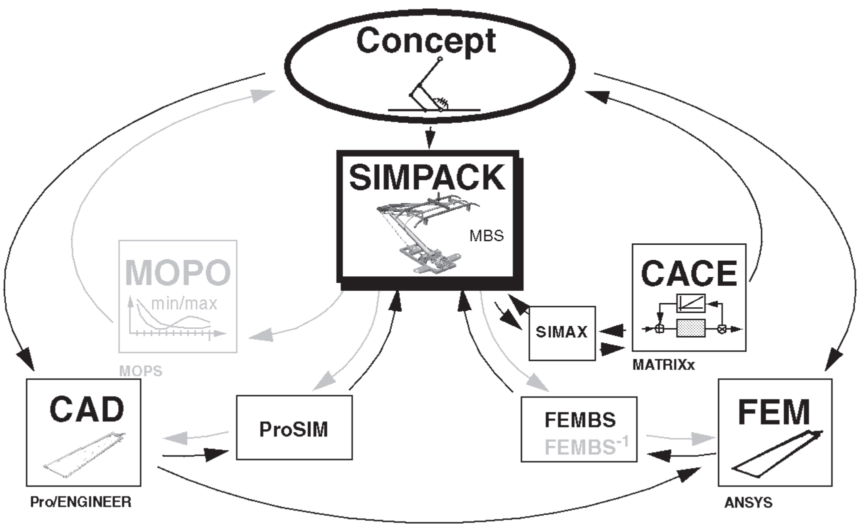
Project Goals

When running with several pantographs in a train set, when tilting trains are employed and when running on low quality catenary sections which have been designed for operation at low speed, the pantograph system becomes the speed limiting factor of a train rather than the running gears. The decisive criterion for assessing the contact quality and consequently the quality of the energy transmission is the time response of the contact force between pantograph slipper and contact wire. Low contact forces result in contact interruptions. If the contact forces are too high, unacceptable catenary lift can occur. Thus active pantographs must allow an adaptation of their vibration-dynamic behaviour to the operational conditions and must efficiently control the contact force variations.

Computer simulations within this project are used to understand the complex dynamic behaviour of the catenary together with the pantograph. It assists in the investigation towards the behaviour of present systems and to predict the characteristics of new or modified concepts. The main focus-point in this project was the implementation of a CAE environment to accelerate the development of new pantograph systems, finding out how to improve the present ones and developing a concept for future controlled systems.

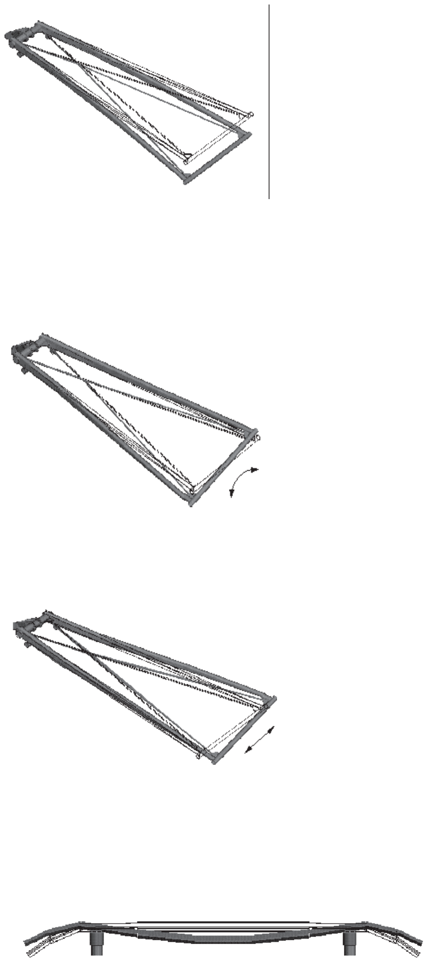
CAE Environment

For a fast and cost effective development of advanced pantographs a range of computer based engineering tools and their interaction is essential. The figure below shows the concept of the modelling, simulation and design environment with the used CAE packages. Since the 3D dynamic behaviour of the pantograph is the key problem of the development, SIMPACK with its extensive interfaces to other prod-



ucts and its suitability to unite different simulation approaches, was placed at the centre of this CAE environment.

The generation of a multi-body simulation model is linked directly to the design of the pantograph using a CAD package, thus providing mass and inertia data in a very early design phase. The corresponding data is exchanged via the interface ProSIM. Since some parts of the pantograph exhibit structural elasticity in the frequency range of interest, FEA models have to be provided as well. The flexible data of these bodies are transformed to SIMPACK by the interface FEMBS. The design of control elements is enabled by the interface SIMAX, allowing the combination of 3D mechanical SIMPACK models with control loops modelled in the CACE tool MATRIXx.



FEA-Calculated Mode Shapes, representing elasticity in the multi-body simulation

Pantograph Simulations

To verify the presented development concept, two passive high performance pantographs, the DSA 350 S and DSA 350 SEK, have been analysed, since numerous measurement data were available. The models, first created in Pro/ENGINEER and then exported to SIMPACK, contain full 3D kinematics. Three bodies, the two contact strips and the upper frame are modelled as elastic bodies. The above mentioned interface FEMBS uses a modal approach to describe elastic bodies in SIMPACK. For the contact strips only the first bending mode is used, the description of the elastic movement of the upper frame requires two bending modes and one torsional mode, as shown besides. The FEA model of the contact strip was set up by using the FEA pre-processor, whereas the mesh of the upper frame was created directly from the CAD data. Finally, the light grey arrows in the figure are options available by the CAE products but not yet employed within that project: A multi-objective parameter optimisation tool allows the automatic optimisation of specific parameters according to chosen criteria functions, the interface LOADS can be used to consider loads obtained from the multi-body simulation in the FE tension analysis.

The behaviour of the whole system was compared to measurements of the so-called apparent mass to verify the complete multi-body model including elastic bodies, structural damping and joint friction. Due to the need of simulating non-linear effects, the result of the frequency response figure aside have been achieved by time integration of the systems response on a number of different excitation frequencies. The result shows the influence of the flexibility of the upper frame and contact strips. The deviations between both, the measured and the simulated frequency response histories are a result of not exactly reproducible excitation conditions of the pantograph on the test rig.

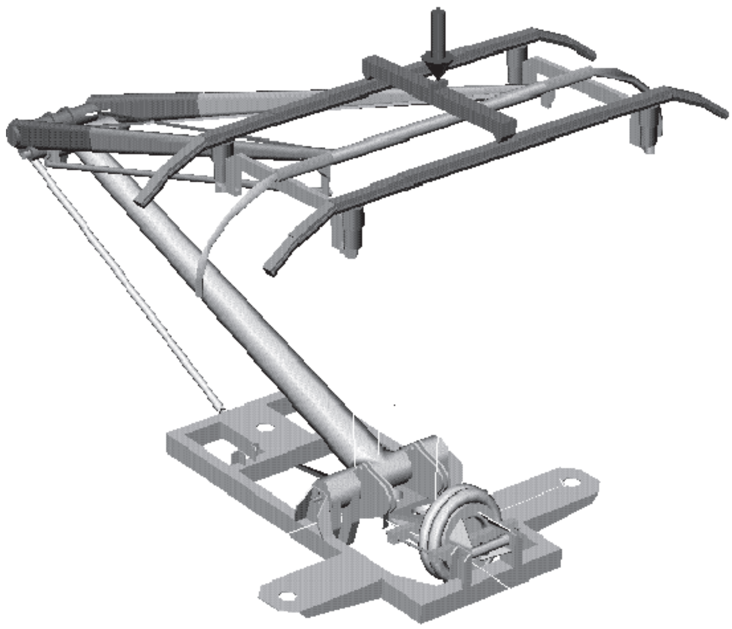
Coupled Pantograph/Catenary Simulation

The rating of new or enhanced pantograph concepts is based mainly on the time history of the contact force and the lift of the contact point while running along overhead lines. For that purpose it is not sufficient to approximate the catenary dynamics by deterministic or stochastic force excitations. These may be applied for basic investigations of the pantograph behaviour, but for simulations striving for verification of new concepts the full catenary dynamics must be taken into account. Therefore PrOSA, a specialised tool for the simulation of catenaries, was coupled to SIMPACK. PrOSA allows to model and solve the partial differential equations needed to describe catenary equations. The original development of PrOSA was performed at the Heinz Nixdorf Institute in Paderborn and is now further developed and validated at the Deutsche Bahn AG. The interface between PrOSA and SIMPACK enables a co-simulation of controlled pantographs and overhead lines. The programs exchange data at discrete time steps using a certain sample rate, up to now realised in a two-process solution. The data exchange is achieved by the IPC-function (Inter Process Communication) elements of UNIX-sockets, while an interface control program ensures a correct synchronisation of the two programs to avoid misinterpretation of the data exchanged. The advantages of this interface concept are that the corresponding system equations can be solved with their own specialised solver and that both tools can be developed independently and even modified fundamentally without compatibility problems, unless the standard of the data exchange format is changed.

New Control Concept

The first control concept, which was developed by using the CAE environment presented including PrOSA, showed its efficiency. It is based on a dynamic isolation of the catenary and the pantograph main frame. In the present realisation of this principle, a passive element is suggested to isolate the contact strips from the pan head by a constant force between both components independent of the relative dynamic motion. In consequence of the relatively small working range, it is necessary to add a control system in order to guarantee the service of the passive element. Therefore an active position control element is planned to influence the lift drive of the pantograph. The applied drive units contain a pneumatic bellow, which introduces a torque in the lower frame by a lever. The first simulations with approximated force excitations or simplified catenary designs showed good improvements achieved with this concept, however, the co-simulation with the catenary program PrOSA showed, that the improvement is less than predicted using the simplified catenary models.

This demonstrated clearly that the influence of the catenary dynamics cannot be neglected. Only the calculation of the full dynamic interaction between both systems can verify new mechatronic approaches.



Johannes Gerl
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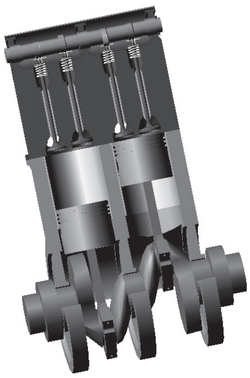
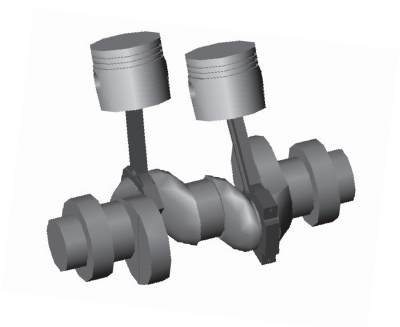
Engine Simulations With SIMPACK

The extensive functionalities of SIMPACK make it an excellent MBS tool for modelling engines, valve controlling systems and engine bearings. Its database concept allows to setup according models with an optimum efficiancy, the quality of its solvers to study high frequency oscillations in detail. As a result of the continuing development of contact models the virtual prototyping of inovative valve controlling systems has become feasible.





Engine Bearing Forces

The forces acting on engine bearings are mostly dependent on the inertia forces resulting from accelerations and decelerations of the pistons and conrods. Also the forces that result directly for the internal combustion have a substantial influence.

The effort required for modelling an engine model to calculate those loads has been reduced to a minimum within SIMPACK. Cylinder units, incorporating piston rods and combustion dynamics, can be saved as substructures to the SIMPACK database and combined into main models to create several possible cylinder layouts (row or V-layout, boxer engine). These substructures can be absorbed within the main model, or remain actively linked to the database to ensure that changes in the substructure are reflected in the main model. Parameterised models can be created so that changes to the model can be made by simply changing parameter values (e.g. cylinder capacity). The interfaces between SIMPACK and CAD systems like Pro/ENGINEER and CATIA that accurate data for mass, inertia and geometry of the engine parts is provided with an optimum efficiency. The algorithm used by SIMPACK to generate the system equations ensures that only a minimal number of equations of motion in terms of relative co-ordinates is needed to describe the system, resulting in optimal calculation speed. This reduced effort required for creating and solving models in SIMPACK leads to a substantial cutback in modelling and analysis costs. The simulation of a two cylinder engine with for instance five thousand rotations per minute is solved in just a few seconds and provides the forces acting on the crankshaft and bearings.

Computer modelling is increasingly used in the application areas of fluid and combustion dynamics. To incorporate the result of a computer simulation or the measurement of the combustion dynamics in SIMPACK, a data-source is required that describes the cylinder pressures or forces as a function of the crankshaft's rotational velocity and angle. A predefined SIMPACK CONTROL module enables this data to be incorporated in a mechanical model.

Engine Mount Design

The engine mounts - rubber bushings as well as hydro-mounts - can be simulated with several models incorporating frequency and amplitude dependent characteristics. A special SIMPACK pre-processor enables the approximation of frequency dependent characteristics by a curve fit of a transfer polynomial and provides automatically provides the bushing elements with the necessary parameters. The use of elastic bodies in SIMPACK allows a thorough analysis of engine mounts interacting with a flexible chassis.

Apart from the solver in the time domain for the analysis and optimisation of engine mounts, a solver in the frequency domain can be used to interpret the characteristics of the engine mounts. These two solvers can also be used with parameter variation calculations and the advanced optimisation module in SIMPACK.

Valve Drive Design

SIMPACK in general and its robust solvers in particular enable very effective analysis of valve systems.

The contact models integrated in SIMPACK for point, line and area contact are ideally suitable for the modelling of valve controlling systems. The contact model for conventional systems, for instance with rocker levers, can be reduced to a numerical and stable contact model described by two curves - one for the cam, the other for the contact area of the rocker lever. The contact surfaces can be defined from within SIMPACK or imported from a CAD-program. A special Spline-Algorithm allows closed splines to be defined, so that contact models of shafts with an unlimited number of revolutions can be simulated.

For the simulation of innovative valve systems with variable valve peaks in order to to replace the damper flap in petrol engines, a contact model between two arbitrarily shaped bodies is used. SIMPACK CONTROL or the combination of SIMPACK with CACE-tools such as MATLAB Simulink or hydraulic and pneumatic simulation tools such as AMESim enable the simulation of electro-magnetic, pneumatic or hydraulic control of the valve actuation.

The contact points for all the different types of geometrical contact models can be modelled rigidly or as a force element, representing elastic deformations of the contact patch. Experience has shown that the brief periods of loss of contact and re-contact between rocker arm and tappet can be simulated effectively without any numerical problems. The root function system integrated into SIMPACK allow the solver to communicate with the contact elements. Consequently the time step will automatically be reduced when an instability in the time integration is suspected. This method ensures that the time step is only reduced when high accuracy and stability is required, while a larger time step is used in other areas to reduce the calculation time. These features of SIMPACK are also apparent when mechatronic models in conjunction with MATLAB Simulink are used as the SIMPACK solver is still responsible for the mechanical model when the co-simulation interface is used.

Camshaft drive systems can be modelled as a simple constant transfer ratio between crankshaft and camshaft. In case their elasticity is a matter of interest more complicated models incorporating elastic belts or chains are used.

Finally, the valve springs can be modelled as elastic bodies, either through the SIMPACK pre-processor BEAM or through an external FEM-program.

La simulazione dei motori con SIMPACK

La estesa funzionalità di SIMPACK rende questa applicazione per sistemi „multi-body“ ideale per la modellizzazione dei motori, delle distribuzioni a valvole ed dei cuscinetti. Il concetto di “database” su cui è basato permette di costruire modelli con grande efficienza ed ottimizzazione, la qualità dei metodi risolutivi permette di studiare oscillazioni ad alta frequenza in dettaglio e, per il continuo sviluppo di modelli di contatto, è divenuto possibile generare innovativi prototipi di distribuzioni a valvole.

Forze sul cuscinetto del motore

Le forze agenti sul cuscinetto del motore sono principalmente dovute alle forze di inerzia risultanti dalle accelerazioni e decellerazioni dei pistoni e delle bielle. Inoltre, anche le forze che vengono generate dalla combustione interna costituiscono un elemento di rilievo. Lo sforzo necessario per modellizzare un motore e per poter quindi calcolare tali forze è stato ridotto al minimo in SIMPACK. I cilindri, i quali comprendono i pistoni, le bielle e la dinamica della combustione, possono essere salvati nella banca dati (“database”) di SIMPACK come sottostrutture le quali possono poi essere assemblate in modelli principali per generare diverse configurazioni (in serie o a V, a sogliola). Queste sottostrutture possono essere inglobate nel modello principale del motore, oppure rimanere attivamente connesse alla banca dati per permettere che cambiamenti nelle stesse vengano eseguiti automaticamente anche nel modello principale. I modelli possono essere parametrizzati in modo che cambiamenti di design possono essere effettuati semplicemente variando i parametri (per esmpio, la cilindrata). L’interfaccia tra SIMPACK e sistemi CAD come Pro/ENGINEER e CATIA permettono di ottenere dati come la massa, la inerzia e la geometria dei componenti del motore, con ottima efficienza. L’algoritmo utilizzato in SIMPACK per generare le equazioni del moto del sistema genera un insieme minimo di equazioni necessario a descrivere il sistema stesso, ottimizzando così il tempo di calcolo.

Questa riduzione di onere necessario a creare e risolvere modelli in SIMPACK permette di ridurre i costi di modellizzazione ed analisi in modo significativo. La simulazione di un motore a due cilindri che opera, ad esempio, a cinque mila giri al minuto, è risolta in pochi secondi e vengono inoltre fornite in uscita le forze agenti sull'albero a gomiti e sul cavalletto. La modellizzazione computazionale viene oggi giorno utilizzata sempre più spesso in aree applicative come la fluidodinamica e la dinamica della combustione. Per introdurre il risultato di una simulazione al computer o le misure di una combustione in SIMPACK, è necessario generare una sorgente dati che descriva la pressione o la forza dei cilindri in funzione della velocità rotazionale o dell'angolo dell'albero a gomoti. Un modulo predefinito di SIMPACK (Simpack CONTROL module) permette di introdurre questi dati nel sistema meccanico.

Progetto dei cuscinetti del motore

I cuscinetti del motore – cuscinetti a gomma oppure cuscinetti idraulici – possono essere simulati con diversi modelli i quali contengono caratteristiche dipendenti dalle frequenze e dalle ampiezze in gioco. Un pre-processore di SIMPACK dedicato permette di eseguire una approssimazione delle caratteristiche che dipendono dalla frequenza tramite la interpolazione di una funzione di trasferimento polinomiale, in modo da ottenere immediatamente gli elementi dei cuscinetti con i parametri necessari. L'utilizzo di elementi elastici in SIMPACK permette una approfondita analisi della interazione tra i cuscinetti ed una struttura flessibile. Oltre alla possibilità di risolvere il moto nel dominio del tempo per la analisi e la ottimizzazione dei cuscinetti, la risoluzione nel dominio della frequenza può essere utilizzata per determinare le caratteristiche degli stessi. Questi due metodi possono essere applicati con una variazione parametrica e con l'avanzato modulo di ottimizzazione di SIMPACK.

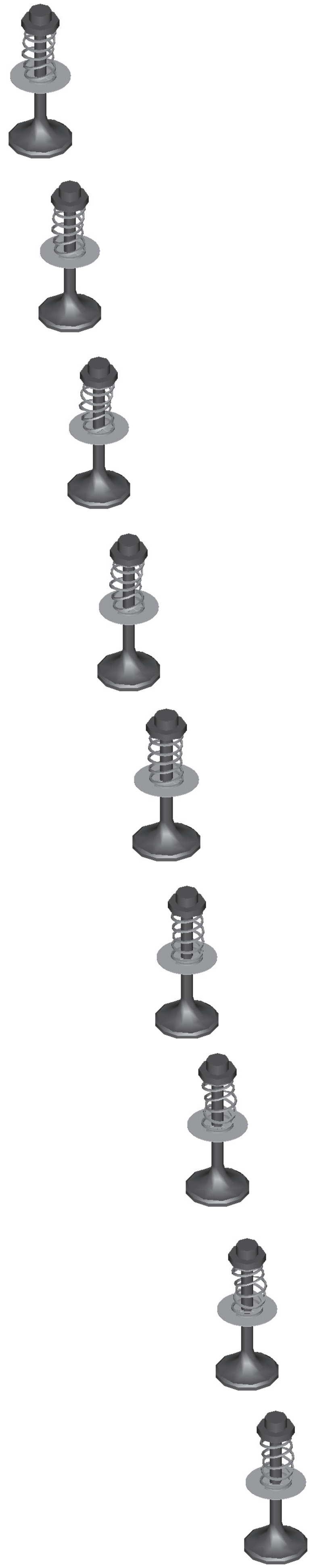
Progetto del sistema delle valvole

Simpack permette di eseguire analisi molto approfondite di sistemi di valvole. I modelli di contatto integrati in SIMPACK per contatto puntuale, di linea o di superficie sono ideali per la modellizzazione di sistemi di controllo di valvole. I modelli di contatto per modelli convenzionali, ad esempio con i bilanceri, possono essere rappresentati con un modello di contatto numerico stabile descritto da due curve – una per la camma, l'altra per l'area di contatto del bilancere. Le superfici di contatto possono essere definite in SIMPACK oppure possono essere importate da un programma CAD. Un algoritmo particolare permette di definire delle curve ("splines") in modo che possano essere simulati modelli di contatto per alberi con un numero illimitato di rivoluzioni. Per la simulazione di sistemi di valvole innovativi con picchi di valvola variabile, in modo da poter rimpiazzare la valvola a farfalla in motori a benzina, viene utilizzato un modello di contatto tra due corpi di forma arbitrariamente definita.

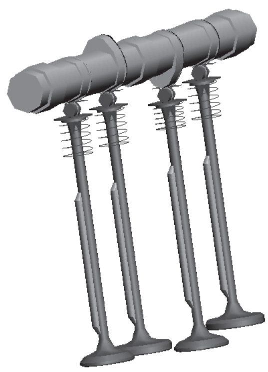
Il modulo SIMPACK CONTROL o la combiazione di SIMPACK con "CACE-tools" come MATLAB Simulink, o sistemi di modellizzazione di sistemi idraulici e pneumatici come AMESim, permettono la simulazione di controlli elettromagnetici, pneumatici o idraulici per l'attuazione delle valvole. I punti di contatto per tutti i tipi di modelli geometrici di contatto possono essere modellizzati rigidamente o elasticamente, rappresentando deformazioni elastiche della zona di contatto. L'esperienza ha dimostrato che i brevi periodi di perdita di contatto e ripresa di contatto tra il bilancere e la camma possono essere simulati con successo senza alcun problema di carattere numerico. Il sistema "root function" integrato in SIMPACK permette l'interazione tra il processo risolutivo e gli elementi di contatto. Di conseguenza, il passo di integrazione temporale viene automaticamente ridotto quando sorge un sospetto di instabilità nella integrazione. Questo metodo assicura che il passo temporale venga ridotto solo quando è richiesto un alto grado di precisione e di stabilità, mentre un passo temporale più lungo può essere utilizzato in altre aree per ridurre il tempo di calcolo complessivo. Queste caratteristiche di SIMPACK sono riscontrate anche per modelli meccatronici utilizzati in congiunzione con MATLAB Simulink, dato che SIMPACK e' comunque responsabile del modello meccanico quando viene utilizzata tale interfaccia di simulazione.

Il comando dell'albero a camme può essere modellizzato come un semplice rapporto tra l'albero a gomiti e l'albero a camme. Nel caso si fosse interessati nella elasticità degli elementi che costituiscono il sistema, possono essere utilizzati modelli piu' complessi che includano chinghie dentate o catene.

Infine, le molle delle valvole sono modellizzate come corpi elastici, attraverso l'utilizzo del pre-processore di SIMPACK BEAM o con l'utilizzo di programmi Fem esterni.



Bending Mode Shape of a Valve Spring



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Deutsches Zentrum für Luft- und Raumfahrt (Germany), Institut für Entwurfsaerodynamik, Institut für Strukturmechanik

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Porsche AG, Weissach (Germany)
Technische Universität Dresden (Germany), Institut für Theoretische Grundlagen der Fahrzeugtechnik
Volkswagen AG, Wolfsburg (Germany)

SIMPACK at Conferences and Exhibitions

21. - 22. 10. 99	Reifen - Fahrwerk - Fahrbahn, Hannover, Germany
4. - 5. 11. 99	VDI/FVT-Tagung Nutzfahrzeuge, München, Germany
23. - 25. 2. 2000	VDI-Tagung Schwingungsdynamik, Düsseldorf, Germany
24. - 25. 2. 2000	Simulation im Maschinenbau, Dresden, Germany

SIMPACK Training

Wheel/Rail Basics

20. and 21. October at INTEC in Oberpfaffenhofen
Contents
Modelling: set-up of railway vehicle models, non-linear and linear contact models (theoretical background and practical use), definition of tracks and excitations, model check and validation, parameterisation and substructuring.
Analysis: time and frequency domain calculations, eigen values, stability analysis, ride comfort analysis, parameter variation, post-processing.
Instructors Andreas Böttcher, Johannes Gerl
Language English

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FEMBS, LOADS,
ProSIM, CatSIM,
SIMAT, SIMAX
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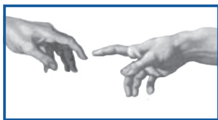

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