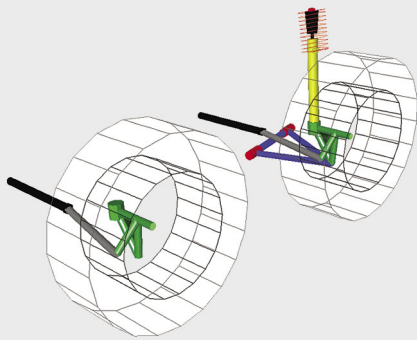


SIMPACK Virtual Suspension



Virtual and standard suspension

In order to improve vehicle performance in terms of handling, stability and ride comfort the usage of controlled systems has increased tremendously. This trend requires the availability of efficient and easy-to-use, three dimensional vehicle models within control system simulation environments. By replacing the detailed kinematic structure of a multi-body suspension model with a simple look-up table based modelling approach, SIMPACK Virtual Suspension now offers an integrated process to reduce the model complexity essential for hardware- and software-in-the-loop simulations.

REQUIREMENTS

3D vehicle models that are used by control system experts do not have to fulfil the same requirements as models used for the design of purely mechanical system parts. The purely mechanical systems need to allow insight into the effects that appear at each single bushing, whereby the control system modeller need only know the behaviour of the suspension as a whole, reducing the complexity of the required model. In addition, the co-operation between the vehicle manufacturer and the system supplier may restrict the release of confidential suspension data.

For the model to be used in a control system environment, it is necessary that equations do not contain differential algebraic equations (DAE), as the solvers in control environments often do not have the functionality to deal with DAEs, the case with MATLAB Simulink. One of the major features of the virtual suspension joint is that the suspension system does not require any DAEs.

KINEMATICS STORED IN LOOK-UP TABLES

The basic idea of SIMPACK's virtual suspension joint is to read-in the position of a suspension system from look-up tables during an analysis, instead of evaluating the system's kinematic behaviour during the calculation. The look-up tables are generated from a previous multi-body system analysis in which SIMPACK writes the suspension kinematics to the tables.

When using the virtual suspension joint to connect the wheel carrier with the chassis body within automotive models, all the connecting bodies that represent the wishbones can be eliminated. The 'dependent' degrees of freedom of the wheel carrier such as the toe and camber angle are therefore stored as a function of the wheel lift and, where applicable, of the steering state. SIMPACK automatically applies splining algorithms to evaluate the relevant function tables whilst the analysis is carried out. The equations of motion that are required to represent the suspension behaviour are reduced and, more importantly, the algebraic equations are avoided. The virtual suspension system modelled in SIMPACK is represented entirely by ODEs. Rear suspensions therefore are modelled with just one degree of freedom (wheel lift) and front suspensions with two degrees of freedom (wheel lift and steering angle).

ADDITIONAL SUSPENSION ELEMENTS

Due to the fact that e.g. wishbone bodies are removed when using the virtual suspension joint, any other element which was referenced to these bodies (like shock absorbers, stabiliser bar) must now be connected to the wheel carrier. This means that, for instance, the stiffness and damping characteristics of a suspension strut must be transformed according to the modified connection points. The SIMPACK Virtual Suspension offers specialised elements for the suspension strut and the stabiliser bar that support the user in carrying out these transformations, avoiding too much manual calculation effort.

Additionally, a steering element designed for the use with the virtual suspension joint is available which makes it easy to connect any external steering input, provided by MATLAB Simulink for example, to the suspension joint.

ELASTO-KINEMATIC SUSPENSION JOINT

When preparing a suspension for the elasto-kinematic virtual suspension joint, additionally to the kinematics, the movement of the wheel carrier as a reaction to certain forces or torques is

Solver	Jump over ramp CPU time [sec]	Steered CPU time [sec]
EULER, fixed step size (MATLAB Simulink)	5,3	20,5
ODE15f stiff/NDF, controlled step size in MATLAB Simulink	3,4	4,6
SODASRT in Co-Simulation with MATLAB (VIRTUAL SUSPENSION)	6,6	18,5
SODASRT in Co-Simulation with MATLAB (SUSPENSION from Auto motive+)	47,9	74,6

Integration has been performed from 0.0 sec to 8.0 sec. The indicated CPU times were output to MATLAB Simulink and include initialisation time and time for the measurement of the outputs from the states.

Calculations have been performed on Intel Pentium III, 866MHz, 261.100 kb RAM.

saved. By adding a certain elastic movement to the kinematic movement of the suspension, the virtual suspension joint can then also take into consideration the elasto-kinematic behaviour of the suspension. The force/torque dependency on the wheel carrier movement can be both a linear or non-linear function.

CREATION OF LOOK-UP TABLES

In order to create the look-up tables required by the virtual suspension joint, an analysis with the SIMPACK module Virtual Testing Lab is carried out. By successive time domain or static equilibrium simulation of the complex suspension model, together with an appropriate test bench template and plot filter, the look-up tables can easily be created. Alternatively, the virtual suspension data format from MSC.ADAMS (scf-files) is supported.

The look-up tables can also be provided from measurement data. For the virtual suspension joint, SIMPACK relies on the function array set data format which is a standard modelling element within SIMPACK and is in ASCII-format.

CALCULATION PERFORMANCE

Due to the significant reduction in the degrees of freedom, vehicle models that are based on the virtual suspension joint show extremely high calculation performance. The table shows a comparison between a fully detailed SIMPACK model and the same model, but using look-up table joints. Kinematic and elasto-kinematic variants were simulated for a double lane change and transition of a road bump. Due to the elimination of algebraic equations (and therefore an ODE representation instead of DAE), a simple explicit Euler time integrator can be used for the model with virtual suspension joints. The simulation performance on a Pentium III (specification see below) with the Euler integrator clearly demonstrates that these kinds of models are suited for real-time simulation.

The models are available for download from www.simpack.com, service/support, model database. They require SIMPACK Version 8618 or higher. Please contact your local SIMPACK distributor to re-

ceive a trial version. A tutorial about how to use the virtual suspension joint is also available.

COMPATIBILITY AND AREAS OF APPLICATION

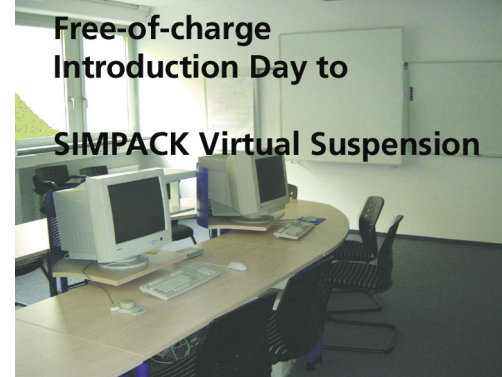
All of the modelling elements that are delivered with the new package SIMPACK Virtual Suspension are fully compatible with all other SIMPACK modules, including SIMPACK Code Export. The virtual suspension joint, as well as the virtual steering, virtual stabiliser bar and virtual suspension strut elements can be stored in SIMPACK databases. It is therefore possible to use one main model with combinations of the complex multi-body suspension model or alternatively with the virtual suspensions, read-in as substructures.

As mentioned in the article SIMPACK Code Export by Dr. Alex Eichberger in this edition of SIMPACK News, the compatibility with SIMPACK Code Exports allows the user to create SIMPACK models that are perfectly suited for SIL and, for the case that certain requirements regarding the creation of code are fulfilled, also HIL simulation. These models can be exported to MATLAB Simulink and other control simulation tools very efficiently, both from a technical and a cost point of view. Therefore, for the first time, a tool is available that offers an integrated process to create multi-body models for both mechanical design purposes of suspensions and the design of control systems.

In spite of the fact that the design of SIMPACK Virtual Suspension was driven mainly by automotive application fields, the approach is not at all limited to automotive models. Users from other areas like railway engineering can benefit from its features, too, for the look-up table joint can be used as a standard SIMPACK joint between arbitrary bodies.

FURTHER STEPS

INTEC is working on the implementation of optimised bumper elements to be used along with the Virtual Suspension increasing the performance, particularly for real-time simulations.



Free-of-charge Introduction Day to

SIMPACK Virtual Suspension

If you are interested in taking part in our free-of-charge introduction day to SIMPACK Virtual Suspension, please contact Ms. Ernie Engert via telephone 0049 8153 9288-40 or send an e-mail to ernie.engert@simpack.de.

SIMPACK Virtual Suspension includes

Joint 094	VirtualJoinF Suspension by Table
Force 063	Virtual Suspension Spring-Damper
Force 064	Virtual Suspension Steering
Force 065	Virtual Suspension Elastokinematics

SIMPACK Virtual Suspension is available with SIMPACK Version 8.619