FEA–MBS–Coupling–Approach for Vehicle Dynamics

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1 Motivation

Both Multibody Systems (MBS) simulations and Finite Element Analysis (FEA) are widely used techniques to model vehicle dynamics.

The first method is used for the analysis of mechanisms consisting of rigid components subject to joints and constraints. MBS is used whenever a large number of rigid parts interact with each other in a complex manner. FEA allows a detailed investigation of the structural behavior of the system. It is mainly used in situations, where the stress–strain response or the deformation of certain parts are of special interest.

Critical situations like driving over an obstacle or through a pothole need an intensive virtual investigation. A typical load case is a vehicle driving at 40 to 60 km/h over a barrier or a cross–drain, resulting in a high–speed dynamic impact, see Figure 1. Most OEMs today use detailed models in FEA for these cases, yet simulating the entire vehicle model and road profile with FEA is very time–consuming. Typical computation times for Abaqus are around 50 hours on 38 CPUs.

Within a joint project between EDAG and a well–known automotive company the usability and accuracy of a new coupled approach was evaluated. The general idea was to replace bigger parts of the previous FEA model by reduced MBS systems and to couple both simulations in a single application. All critical components with nonlinear deformations can be calculated in Abaqus with the same accuracy as in the full FEA model. However the majority of parts are modeled as rigid bodies or flexible superelements in MSC.Adams with less complexity. These MBS system models are re–used from the standard vehicle dynamics workflows. Both models can be coupled through the standard interface MpCCI.

Figure 1: Driving over a pothole or cross–drain [1].

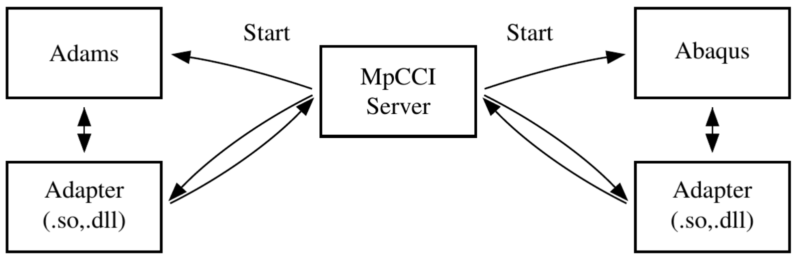

Figure 2: The modularity of MpCCI.

2 Co–Simulation using MpCCI

MpCCI[1] is an application independent interface for the coupling of different simulation codes developed at the Fraunhofer institute SCAI. The MpCCI server starts the simulation codes and handles data exchange between two or more MpCCI code adapters on an abstract level. An MpCCI code adapter is a shared library that implements the data exchange between the server and a specific simulation code, see Figure 2.

Static as well as transient problems can be coupled using MpCCI. Quantities are transferred together with time and/or iteration tags. For static problems, data is exchanged in every iteration. For transient problems the exchange takes place in every time step. MpCCI also supports implicit coupling for transient problems, i.e. data is exchanged more than once per time step. Thus weak as well as strong coupling are possible. In the case of non–matching time step sizes, the exchanged data is interpolated in time.

Different algorithms for the data exchange are supported. In the Gauß–Seidel approach, one code performs a step first and then sends data to its partner. The other code receives the data, performs a step and sends data back. In the Gauß–Jacobi method, on the other hand, both codes exchange data and then perform a step simultaneously.

3 Communication and Stability

Specifically for the MBS–FEA coupling, the coupling region consists of a set of points connecting the rigid part of the system with the FEA model. On the MBS side, i.e. MSC.Adams, so called `GFORCE` or `MOTION` elements are placed on the points that are to be coupled with Abaqus. The coupling region on the Abaqus side is defined using node sets (`NSET`). Quantities are exchanged using boundary conditions or sensors defined on these node sets.

We observed that the stability of the coupled simulation is influenced not only by the geometry of the coupling interface, but also by the choice of the exchanged data. For the tested application of driving over an obstacle, a setup where MSC.Adams sends point positions to Abaqus and receives forces in exchange led to an instability on the Abaqus side. A setup in which MSC.Adams sends forces and receives accelerations resulted in a solver error on the MSC.Adams side. If MSC.Adams sends accelerations and receives forces from Abaqus, stability could be achieved even for large systems.

In addition, the coupling time step size plays a decisive role for the stability of the simulation. Each code uses its own time step size and the MpCCI user can choose

[1]Multiphysics Code Coupling Interface

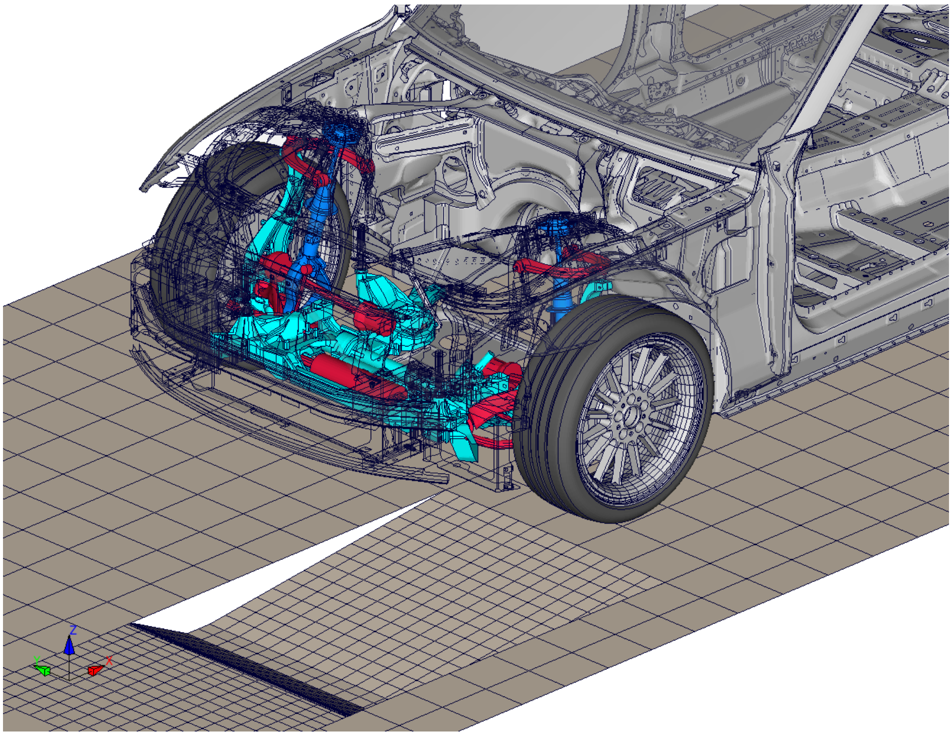

Figure 3: A possible MBS–FEA coupling setup.

an optional fixed time interval for the exchange of data. Our tests show that smaller coupling step sizes result in more stable simulations. A coupling step size of 10^{-6} seconds led to stable simulations and time step sizes of 10^{-5} seconds and above failed due to instability.

Finally, in situations where the MSC.Adams time step is much smaller than the time step size of Abaqus or the coupling time step, the MSC.Adams adapter offers an additional feature to increase stability. A semi–implicit coupling method relates the quantities sent by MSC.Adams to those received from Abaqus. This relation can be used in later time steps to extrapolate FEA data and make it available to the MBS code, even if no data from Abaqus is available yet [2, 3].

4 Applications and Results

The usability and accuracy of the coupling approach has been tested mainly for the scenario of a vehicle driving over an obstacle. The MBS model is a Demo full vehicle assembly included in the MSC.Adams installation. The following levels of detail in the FEA model were examined:

- Road profile and one wheel modeled in Abaqus. The coupling region consists of one attachment point at the wheel.
- Road profile and four wheels modeled in Abaqus. The coupling region consists of four attachment points, one at each wheel.
- Road profile, one wheel and a double wishbone suspension modeled in Abaqus. There are five coupling points between the chassis and the suspension.

- Road profile, two wheels and the entire front wheel suspension modeled in Abaqus. There are ten coupling points between the chassis and the suspension, see Figure 3.

Combinations with Abaqus/Standard were used for stationary cases and investigations of only few components with linear deformations. Abaqus/Explicit is coupled to MSC.Adams for all transient models and mostly nonlinear deformations.

In the course of the study the MpCCI capabilities have been improved. MpCCI now fully supports the MSC.Adams template products Adams Car and Adams Chassis. Issues concerning the data exchange with previous versions of Abaqus have been overcome by using a FORTRAN user subroutine. The user subroutine is called by Abaqus to evaluate an amplitude statement defined in the input file. The data exchange between the MpCCI Code adapter and Abaqus is initiated from within the user subroutine.

Within the collaboration project EDAG demonstrated that the simulation results in the coupled MSC.Adams-MpCCI-Abaqus approach are as good and detailed as the full standalone FEA Abaqus model.

The CPU consumption for the coupled approach was smaller than for the standalone FEA model in all examined cases. Specifically for the simulation, where the Abaqus model includes the front tires and suspension, the coupled MBS–FEA calculation required only 8 hours on 8+1 CPUs, while the standalone Abaqus simulation required 50 hours on 38 CPUs.

The coupled MBS–FEA approach is undergoing continuous optimization concerning the coupling configuration, the MSC.Adams model, the stability of the co–simulation as well as the examined test rigs. In the near future applications including simulations with a deformable steering column or stiffening plate, validation of tire models and component testing for different driving maneuvers can profit from MBS–FEA coupling.

References

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[2] Ilja Kalmykov. Entwicklung einer Schnittstelle für die Co–Simulation im Bereich der MKS–, FEM– und Systemcodes mit MSC.Adams, Abaqus und Matlab. Master's thesis, Universität Kassel, 2012.

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