Simulating Vehicle Extreme Load Cases with Adams-Marc Co-Simulation

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Introduction

Efficiently designing and testing mechanical systems for automobiles is a challenge for some engineers due to lack of a smooth integration between, for example, system dynamics and finite element analysis (FEA) software domains. An MSC Adams-Marc co-simulation product toolchain enables engineers to perform multiphysics simulations between Marc nonlinear FE technology and the Adams Multibody Dynamics (MBD) code. By so doing, multibody dynamics engineers can increase model accuracy by including non-linear structural behavior; and Finite Element Analysis (FEA) engineers can study components with realistic boundary conditions. Coupling the technologies also produces time savings for nonlinear FEA software users, since some of the rigid moving parts can be solved in Adams, which dramatically decreases the total solution time.

THE 'POLE RUN OVER' ENGINEERING CHALLENGE

A vehicle can be subject to high impact loads a few times during its life cycle. These load cases are often referred to as 'peak loads' or 'strength events' and play a major role in the product development of a vehicle since they potentially drive the design for several components. One of the important load cases is the "Pole Run Over" (Figure 1), which means that the underbody of the vehicle is scratched by an obstacle (e.g. a stone on the ground), and suffers large deformation. The

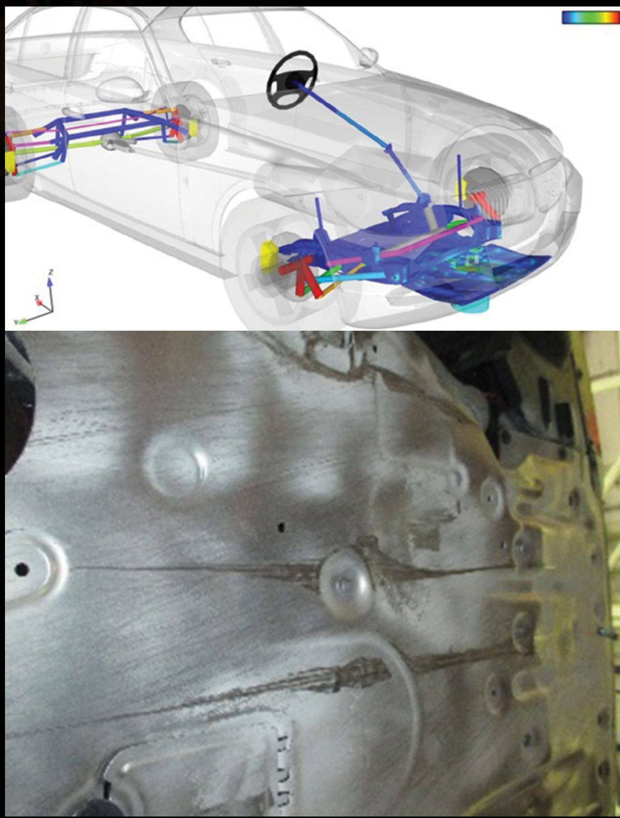

Figure 1. Extreme Load Case: Pole Run Over

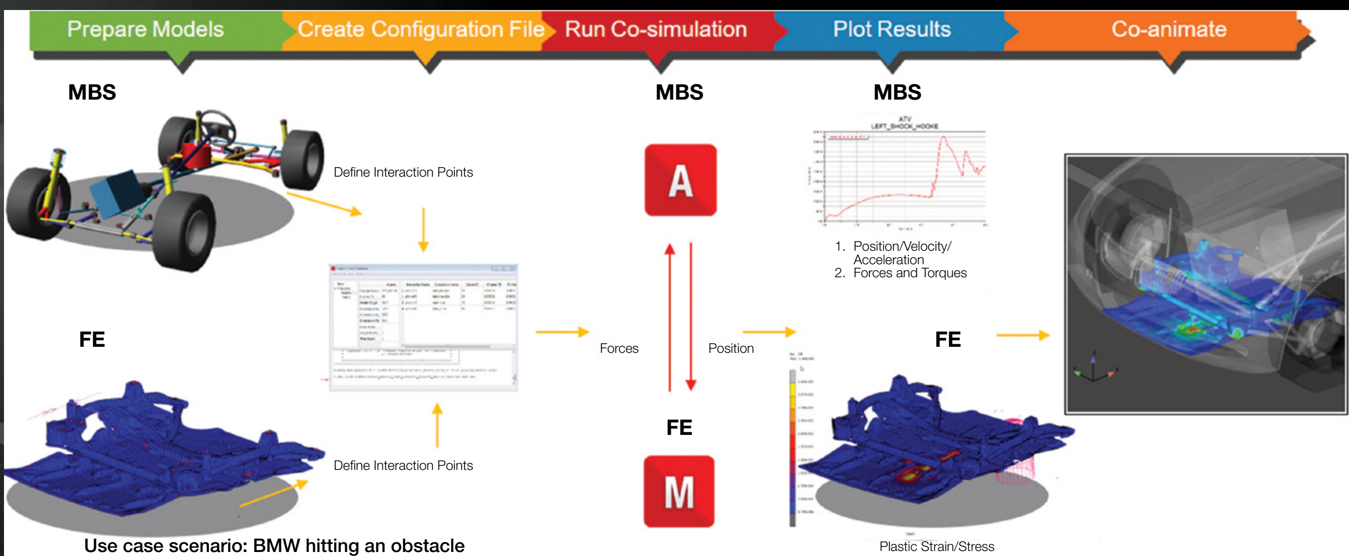

Figure 2. Typical Adams-Marc Co-Simulation Automotive Toolchain Workflow

challenge with a traditional MBD approach is that plastic deformation of the underbody can't be captured during a full vehicle analysis, and if the engineers try to simulate the entire vehicle in an FEA environment, it could take weeks to finish even one simulation [1].

COUPLED CAE SOLUTION

I. Adams-Marc Co-simulation

To address the challenges above, MSC worked with the end users together to implement a mixed MBD + non-linear FEA model which brings the best from both worlds (Figure 2). Non-linear FEA can't be used to accurately describe the non-linear behavior of flexible components, including plastic deformation, non-linear materials, large deformation of the components, buckling, self-contact. MBD can be leveraged to accurately model the system/moving mechanisms, providing realistic boundary conditions for the non-linear components with high efficiency. Hence, a mixed model will also simulate much faster than a complete model in non-linear FEA, and it will still provide the required level of accuracy.

The points at which a model interacts with another model are called interactions. At each interaction point there must be:

- A MARKER and a GFORCE in the Adams model.
- A NODE in the Marc model. The interface NODE in the Marc model must have 6 degrees of freedom

In all Adams-Marc interactions, Adams passes displacements to be imposed on a NODE in Marc. Marc passes force/torque values to Adams to be used in a GFORCE.

II. Model Preparation

The full vehicle model used in this study came from a correlated BMW Adams Car vehicle dynamics model (Figure 3), and it contains about 250 DOFs (Degrees of Freedom), with 13 subsystems. There are 14 interaction points between the MBD and the FEA model, and 14 MARKERs and GFORCEs were defined in the Adams Car templates to communicate with the Marc model.

The BMW Chassis underbody was modeled in the Marc environment (Figure 4), with 11 deformable contact bodies, 200,000 DOFs and 33,000 nodes. The pole was also defined in the Marc model as a rigid body, and 14 interaction points were controlled by 14 nodes as the new boundary condition for this Marc model.

III. Physical Testing

During physical testing, the same maneuver was applied as the CAE simulation event: the full vehicle is driven over a measurement bollard at 30 km/h, and the bollard height is defined dependent on the height setup of the vehicle. The bollard (Figure 5) worked as the obstacle that scratches the chassis underbody (Figure 6), and at the same time, it measures the contact force between the obstacle and the underbody. That force was later used to correlate with the simulation results.

RESULTS AND CORRELATION

Overall, the Adams-Marc co-simulation showed an impressive result compared with the physical testing measurement. From the plot below (Figure 7), the red curve represents the physical measurement of the contact force in the Z direction. The light blue curve came from the first run with the co-simulation without any tuning of the models, and the relatively large discrepancy between the simulation and testing on the peak load is due to the fact that the wrong Y coordinate was provided to the simulation engineers. And because of that, the simulated event missed the contact point between a screw on the underbody and the obstacle which caused the peak load.

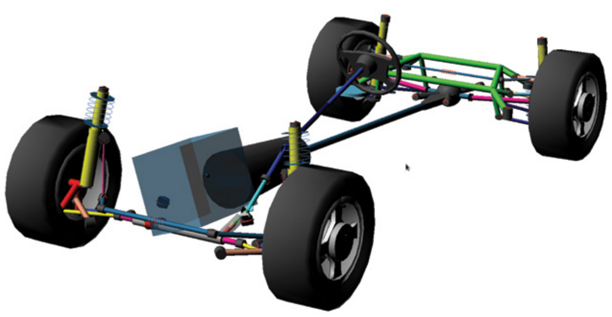

Figure 3. Adams Full Vehicle Model

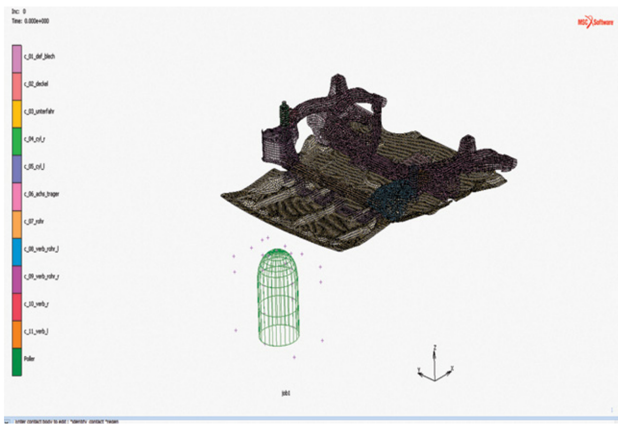

Figure 4. Marc Model for the Chassis Underbody

After the engineers adjusted the Y coordinate in the simulation model and conducted another co-simulation, the black curve was generated which is much closer to the physical testing result. In this attempt, the screw was only added to the Marc model as an assumption, rather than a detailed modeling of the screw itself, and that explains the remaining difference between the co-simulation result and the testing result.

Further analysis has been conducted with even better correlation between the co-simulation results and the testing results, and due to confidentiality reasons, those plots couldn't be shown in this article. Co-animation (Figure 8) was also produced by reading in Adams and Marc results files to CEI Ensight.

To sum up, with the Adams-Marc co-simulation methodology, auto OEM engineers and MSC were able to find a good correlation between the physical testing results and the simulation results within one day, which proved that this co-simulation technology can be used to accurately and efficiently predict the dynamic loads on the vehicle even under extreme load cases.

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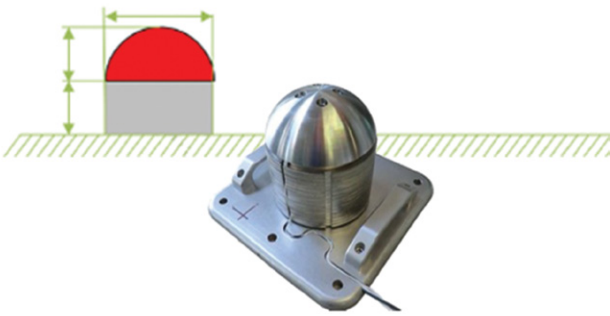

Figure 5. The Measurement Bollard

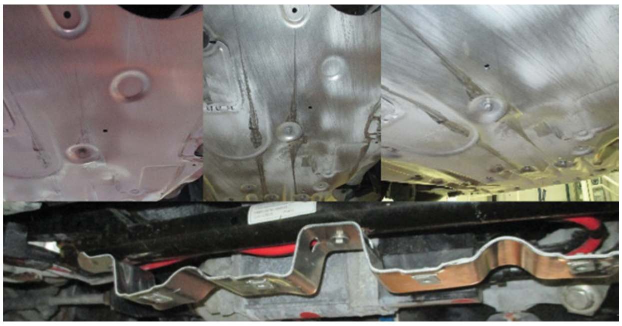

Figure 6. Scratches of the Underbody after the Physical Testing

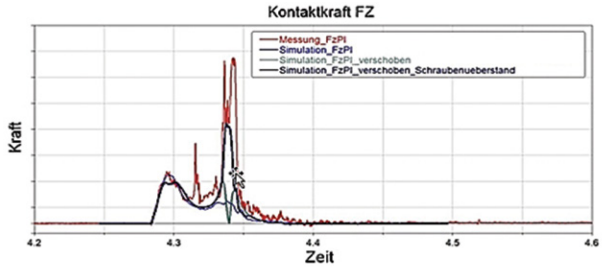

Figure 7. Contact Force Comparison: Physical Testing vs Co-Simulation Results

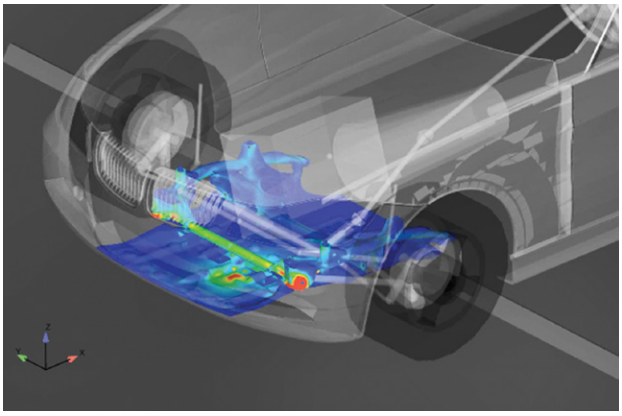

Figure 8. BMW Car Co-animation picture of Pole Run Over done by Adams & Marc and visualized in CEI Ensight

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