MoRePaS 2015

Model Reduction of a Nonlinear Crash Model of a Racing Kart

J. Fehr[1], D. Grunert[1], P. Holzwarth[1], and P. Eberhard[1]

[1]Institute of Engineering and Computational Mechanics, University of Stuttgart, Stuttgart, Germany

Nowadays, crash simulation with commercial Finite-Element (FE) software is a core area of vehicle development. Bearing in mind that crash simulation is among the most calculation-time consuming task in car design, the usage of model reduction for speed-up and data reduction is a logical consequence. The dynamical behavior of a racing kart, depicted in Fig. 1, crashing into a rigid pole and exhibiting a plastic deformation, see Fig. 2, should be approximated by a reduced order model in LS-DYNA. The racing kart is a simple automobile. Hence, its crash behavior is strongly influenced by the nonlinear plastic deformation characteristics of the frame. Therefore, the kart frame is an ideal example to discuss the performance of various model reduction methods for structures in crashes.
In a crash scenario, some parts of the automobile exhibit large deformations, whereas others experience merely small linear vibrations [1]. In order to determine which parts of the model exhibit deformations and which can be considered as linear, it is necessary to run multiple simulations with varying parameters, e.g. impact velocity, in an offline step. Similar to passenger cars in frontal crashes, the plastic deformation in the rear of the kart is rather small. As a consequence, this part is an area where an approximation with linear ansatz functions is suitable. Subsequent to the substructure decision, the correct modeling and handling of the interfaces between the linearly approximated and nonlinear part, see e.g. [2], is decisive for good reduction results. For the calculation of the linear ansatz functions, the nonlinear FE equation $\boldsymbol{M}_e \cdot \ddot{\boldsymbol{q}}(t) + \boldsymbol{k}_e(\boldsymbol{q}, \dot{\boldsymbol{q}}, t) = \boldsymbol{f}(t)$ is linearized with the help of the implicit solver option of LS-DYNA to a second order linear time invariant system $\boldsymbol{M}_e \cdot \ddot{\boldsymbol{q}}(t) + \boldsymbol{K}_e^{\text{tang}} \cdot \boldsymbol{q}(t) = \boldsymbol{f}(t)$ where the elastic stiffness vector $\boldsymbol{k}_e(\boldsymbol{q}, \dot{\boldsymbol{q}}, t)$ is approximated by the tangential stiffness matrix $\boldsymbol{K}_e^{\text{tang}}$ times the deformations. Afterwards, the linearized model of the nonlinear LS-DYNA model is imported into MatMorembs and the linear ansatz functions are calculated by model based projection methods, e.g., Krylov, Gram, modal. Finally, the reduced model consisting of a linear reduced part and a nonlinear part is simulated with LS-DYNA in the online step. To evaluate the performance of the applied approach, the accelerations of the driver calculated with various reduction and parameter settings are compared with the accelerations measured when the original, unreduced nonlinear model is simulated.

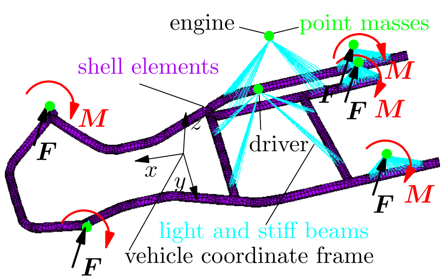

Figure 1: Racing kart used as a surrogate model.

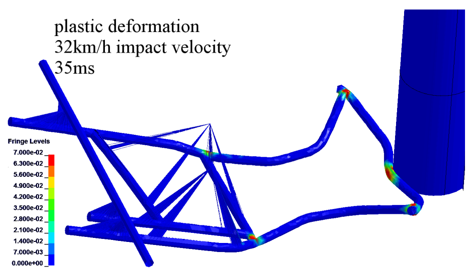

Figure 2: Plastic strain after 35 ms.

References

[1] J. Fehr and D. Grunert. Model reduction and clustering techniques for crash simulations. *Proceedings in Applied Mathematics and Mechanics*, accepted for publication, 2015.

[2] P. Holzwarth and P. Eberhard. Interface reduction for CMS methods and alternative model order reduction. *Proceedings of the 8th International Conference on Mathematical Modelling*, 2015.