Challenges and Experiences in Model Reduction for Mechanical Systems Illustrated for the Reduction of a Crankshaft

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One important step in the development process of technical products is the digital evaluation, like the simulation of technical systems modelled as elastic multibody system. One basic instrument to describe flexibility of mechanical parts is the method of finite elements. The need of high precision and complex geometries leads to a fine spatial discretization. Mathematically the elastic body is descriped by a large set of linear ordinary differential equations, which increase the time to solve. Linear model reduction is a decisive component to simulate efficiently, see [1].
Currently reduction techniques based on modal reduction, sub-structuring and condensation, like component mode synthesis (CMS or Craig-Bampton), are preferred in industrial environments. Pushed by promising results for large scale dynamical systems and a lack of error estimators, a joint FVV research project investigates the use of modern model reduction techniques. A series of reduction techniques, based on Krylov subspaces or Gramian matrices have been developed in addition to the traditional modal approaches in the last years. An overview about the current state of developments can be found e.g. in [2].
It is the objective of this talk to show some important aspects of the use of modern reduction techniques for large mechanical industrial problems. As aexample the flexible crankshaft in various discretization levels from the FVV research project is taken. Due to the large number of inputs and outputs Krylov subspace based model reduction becomes inflexible. Model reduction based on the frequency weighted Gramian matrices is prefered. As explained in [3] the matrix integral needed for calculating the Gramian matrices can be approximated by quadratures using integral kernel snapshots. For efficient calculation of the kernel snapshots a Greedy search algorithm from the reduced basis community is used. The key aspect of the Greedy search algorithm is the existence of an efficient error estimator. In this work the error estimator in [4] is utilized. This estimator is based on the fact that frequently in mechanical systems a certain frequency range $\mathcal{I}_f = \begin{bmatrix}\omega_{min} & \omega_{max}\end{bmatrix}$ is of special interest. Here some advantages of the new reduction methods are shown in the frequency and time domain, like the good error correlation between error estimator and real error and the decrease of the error respectively the approvement of the reproduction quality as compared with traditional reduction techniques.

References

[1] Willems, J.: In Control, Almost from the Beginning Until the Day After Tomorrow. European Journal of Control, Vol. 13, No. 1, pp. 71–83, 2007.

[2] Schilders, W.; van der Vorst, H.; Rommes, J. (Eds.): Model Order Reduction. Berlin: Springer, 2008.

[3] Fehr, J.; Fischer, M.; Haasdonk, B.; Eberhard, P.: Snapshot-based Approximation of Frequency-weighted Gramian Matrices for Model Reduction in Multibody Dynamics. In Proceedings Model Reduction of Parametrized Systems MoRePaS 09, Münster, Germany, 2009.

[4] Konkel, Y.; Farle, O.; Dyczij-Edlinger, R.: Ein Fehlerschätzer für die Krylov-Unterraum basierte Ordnungsreduktion zeitharmonischer Anregungsprobleme. In B. Lohmann; A. Kugi (Eds.) Tagungsband GMA-Fachausschuss 1.30 “Modellbildung, Identifikation und Simulation in der Automatisierungstechnik” (in German), VDI/VDE-GMA, Anif/Salzburg: Technische Universität Wien, Institut für Automatisierungs- und Regelungstechnik, 2008.