Development of a flexible multibody simulation package for in-house benchmarking

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Abstract

An important problem that many multibody research groups face, is the lack of a general, Matlab-based flexible multibody simulation package that is capable of simulating different body formulations and different model order reduction schemes (e.g. Generalized Component Mode Synthesis (GCMS) [1][2] and Global Modal Parametrization (GMP) [3]) in order to compare and benchmark them. There currently exists no simulation package that allows researchers to do that in an easy fashion. Commercial and research-oriented multibody software packages typically provide an end-user friendly environment with various pre- and post-processing support tools and features, often at the expense of versatility and easy access to modify or add certain joint or body formulations or solver settings.

In order to let researchers easily and intuitively find their way in the code, a simulation package has been developed in object-oriented Matlab code. This also allows researchers to easily implement existing Matlab code. The main advantage of this simulation package is that researchers no longer need to develop a full multibody code to benchmark their algorithm. Once researchers have developed their body formulation, they no longer need to worry about how to apply forces or how to add joints. This is achieved by making abstraction of the bodies. Bodies in the simulation package are represented by inertial forces, internal forces, and a set of connection points. All communication between bodies on the one hand and forces and joints on the other hand happens through the connection points, which have a universal definition. This means that forces and joints do not need to know anything about the bodies and which body formulation is used to define them. Whether the connection point is defined on a body using natural coordinates, generalized coordinates, or any other coordinates set, the connection point itself has a universal definition such as a position and a rotation matrix.

This level of abstraction allows the rest of the implementation of the simulation package to become independent of the specific body definition that is used. Whether researchers are modeling a rigid body based on natural coordinates or a flexible body based on a Floating Frame of Reference Formulation (FFRF) [4], the implementation of the multibody code outside of the bodies is universal. This makes the simulation package suited to benchmark different body formulations and different model order reduction schemes.

This allows the simulation package to be easily used for different cases and scenarios and thus it allows researchers to easily compare different body formulations. Once they have a full description of the inertial and internal forces as well as the connection points, they can use their body formulation in any previously defined case and scenario.

As an example, the simulation results of a 3 dimensional slider-crank mechanism (as can be seen in figure 1) are compared for a rigid crank, a flexible crank based on a FFRF method and another flexible crank based on a GCMS method. All cases are solved using a Generalized-α solver [5]. Both flexible bodies take 2 free-free eigenmodes into account. Figure 2 shows the acceleration of the slider as a function of the crank angle for the second half of the simulation. The FFRF and GCMS implementations produce slightly different results due to the inherent nature of both formulations. The fact that both formulations do result in different simulation results when used in a complete multibody simulation is information that is very useful for researchers to continue their work. This difference might not show up in simpler cases and it might be completely overlooked.

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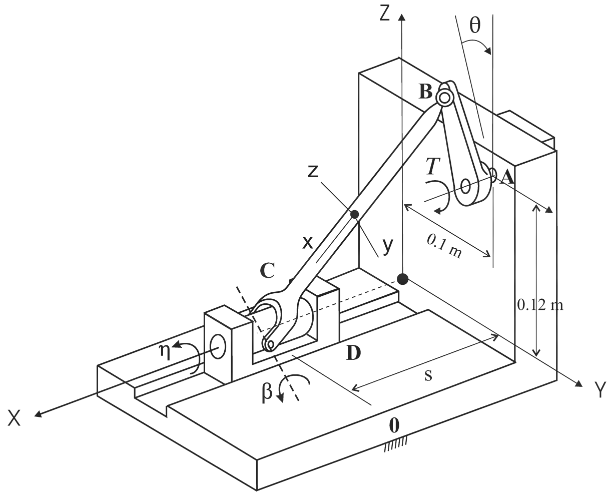

Figure 1: Modeled Slider-Crank Mechanism

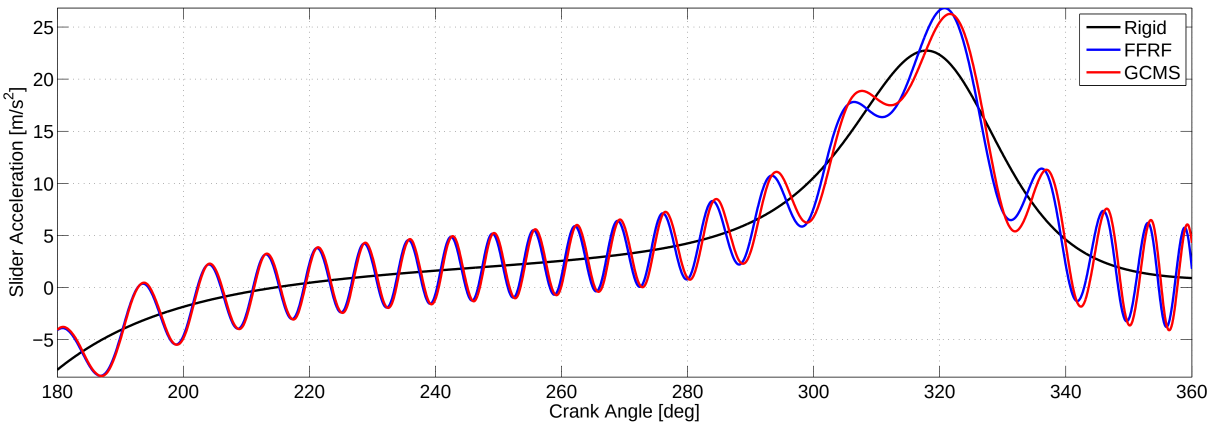

Figure 2: Slider acceleration as a function of the crank angle for different crank types.

References

[1] P. Ziegler, A. Humer, A. Pechstein, J. Gerstmayr. Generalized component mode synthesis for the spatial motion of flexible bodies with large rotations about one axis. In Proceedings of the ASME 2013 International Design Engineering Technical Conference & Computers and Information in Engineering Conference (IDETC/CIE 2013).

[2] A. Pechstein, D. Reischl, J. Gerstmayr. A Generalized Component Mode Synthesis Approach for Flexible Multibody Systems With a Constant Mass Matrix. Journal of Computational and Nonlinear Dynamics 8(1), Aug 31, 2012

[3] F. Naets, T. Tamarozzi, G.H.K. Heirman, W. Desmet. Real-time flexible multibody simulation with Global Modal Parameterization. Multibody System Dynamics, March 2012, Volume 27, Issue 3, pp 267-284

[4] Ahmed A. Shabana. Dynamics of Multibody Systems. Cambridge University Press, 2005.

[5] O. Brüls, M. Arnold. The Generalized-α Scheme as a Linear Multistep Integrator: Toward a General Mechatronic Simulator In Journal of Computational and Nonlinear Dynamics, October 2008, Vol. 3.