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FREEDYN – A MULTIBODY SIMULATION RESEARCH CODE

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The present paper introduces the non-commercial academic MBS-software FREEDYN, which is currently developed at the University of Applied Sciences Upper Austria. Special attention is turned on the efficient computation of highly nonlinear multibody dynamics systems including flexible components arising in nearly every industrial brunch. A fast and accurate simulation code and its open-source release are the main goals.

The most common strategy for including flexible bodies in multibody systems is the floating frame of reference formulation (FFRF) [6,10], which is based on separating the overall motion of the elastic body into a large rigid body motion (or reference motion) and superimposed small deformations [5,9]. The inertia forces of a flexible body in the FFRF are given by

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\mathbf{q}}}\right)^T - \left(\frac{\partial T}{\partial \mathbf{q}}\right)^T = \mathbf{M}\ddot{\mathbf{q}} + \dot{\mathbf{M}}\dot{\mathbf{q}} - \left(\frac{\partial T}{\partial \mathbf{q}}\right)^T \tag{1}$$

in which T represents the kinetic energy and $\mathbf{M}$ is the mass matrix of the body. For solving the equations of motion of a flexible multibody system, the computation of the Jacobian matrix plays a fundamental role. Analytically derived expressions for the matrices in the Jacobian lead to significant improvements in terms of computational burden, [3], as compared to the time-consuming numerical computation of the Jacobian. As an additional improvement of efficiency, the mass matrix of the system as well as the matrices used in the Jacobian can be represented in terms of a set of inertia shape integrals which depend on the assumed displacement fields, see [8]. These inertia shape integrals have to be computed only once in a pre-processing step, while the matrices have to be updated in every step of the time integration since they depend on the generalized coordinate vector $\mathbf{q}$. Moreover, a simplification of the inertia forces has been performed using Euler parameters as rotation parametrization. The advantage of using Euler parameters is their singularity-free description of rotations. Furthermore, without loss of generality, eigenvectors of the unrestrained deformable body are used for representing the elastic deformations, which are also known as free-free modes. This assumption represents no restriction, since an arbitrary set of shape functions can always be transformed into shape functions having the beneficial properties of free-free modes, see [1,7].

The latter mentioned analytical investigations as well as the simplifications concerning Euler parametrization and the usage of inertia shape integrals in the framework of the MBS-software FRREEDYN enable an accurate and efficient computation of nonlinear multibody dynamics described by a system of algebraic and differential equations. Moreover, it may also be used for integrating the adjoint system of equations, which allow the application of an extremely powerful approach to solve various optimization problems for multibody systems. In FREEDYN, the well-established Hilbert-Hughes-Taylor (HHT) method, [2,4], is used for the numerical time integration of the equations of motion. The HHT method, also known as the α-method, serves as a numerical integrator for differential algebraic equations given in an index 3 formulation.

The present paper introduces the new MBS-software FREEDYN and its current status of development. Several examples have been performed in order to show its user-friendly applicability and its accuracy and efficiency according to the analytically derived components of the Jacobian matrix as well as their description using inertia shape integrals.

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