Large Scale Simulation of Flexible Multibody Systems

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ABSTRACT

The so-called absolute nodal coordinate formulation has been developed in order to simulate large deformation problems especially for beam and plate structures. A substantial number of publications, numerical simulations and verification of physical experiments show potential applications and advantages of the absolute nodal coordinate formulation, such as a constant mass matrix and the ability to solve large deformation problems with correct rigid body inertia terms. The nature of finite elements based on the absolute nodal coordinate formulation differs significantly from standard finite elements as this formulation is positioned between solid and structural finite elements and the degrees of freedom are based on nodal slopes and position rather than nodal displacements. Constant mass matrix, standard stress and strain definitions as in solid finite elements and the availability of beam and shell elements with high aspect ratio make this formulation attractive for multibody system simulation. In commercial programs, flexible bodies are only available through adding static modes and eigen-modes of a structure to a multibody system. In this so-called component mode synthesis, which is based on linear superposition, nonlinear geometrical or physical nonlinear behavior has yet not been made available.

While the original absolute nodal coordinate formulation of 3D beam and plate elements suffers from locking effects, state of the art methods to avoid those effects are presented in the talk. A modification of the terms for the virtual work of internal energy as well as higher order elements are introduced in order to gain a better convergence.

The computational effort for the residual in every time step is significantly reduced by means of a special sequence of the evaluation of the terms for the virtual work of internal forces. In the context of general rigid and flexible multibody systems with algebraic constraints, a re-ordering of the equations of motion and the use of sparse matrix manipulation leads to an almost linear growth of computational time with respect to the number of bodies. Stiff time integration codes based on implicit Runge Kutta methods have been developed and successfully applied to the investigated elements. A comparison with free available time integration codes shows that popular multistep solvers are not applicable to certain stiff equations of motion. A specific simplification of the Green strain tensor further more speeds up the formulation by means of transforming the Jacobian of the Newton method into constant and varying terms.

Commercial multibody codes are usually limited to the use of several hundreds of degrees of freedom, otherwise the numerical simulation takes days. The investigated examples with the proposed numerical techniques and several thousands of degrees of freedom take just several hours. Numerical examples are presented which show the improved accuracy and efficiency compared to existing results from the literature. As an industrial application the advantages of the proposed methods are demonstrated by using a three dimensional pantograph-catenary system which is up to now not possible to simulate with a commercial multibody code.

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