INTEGRATING NONLINEAR FINITE ELEMENTS WITH MULTIBODY SIMULATION

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ABSTRACT

Demand for capturing nonlinear flexibility in dynamic simulation of multibody systems is increasing in the analysis of automotive and aerospace structures. Classical methods of modelling flexible multibody system such as the floating frame of reference formulation and component mode synthesis are limited to linear behavior. Various approaches to overcome this limitation such as absolute nodal coordinate formulation (ANCF) and MBD-FEA co-simulation show promise, but come with their own limitations and drawbacks. This paper presents another method of modelling flexible systems that fully couples nonlinear finite elements with multibody dynamics. This method has been implemented in Adams by integrating nonlinear finite element technology from MSC.Nastran.

In this method nonlinear FE equations are fully embedded into the MBD model as an external system with General State Equations (GSE). These equation sets are assembled as part of the MBD system and solved simultaneously by a single numerical integrator in time. This integrated solution is based on a single solver approach and increases the ease of modelling and reuse of finite element technology to model nonlinear phenomena such as large deformation, material nonlinearity and contact in flexible multibody systems. The objective of this work is to reuse existing nonlinear FE models that have been validated at the component level, as bodies in MBD.

Some of the challenges of integrating nonlinear finite elements with multibody dynamics are the treatment of large rotation and the large number of degrees of freedom (DOF) that are typically found in finite element models. Nonlinear finite element formulations commonly employ incremental rotations that are updated at each time step to achieve overall large rotations; whereas, multibody dynamics formulates the equations of motion in full rotation. There are no limitations on rotation in MBD formulations. This requires functional relationships to be developed to convert incremental rotation to full rotation so that existing nonlinear FEA can be used in an integrated and consistent solution.

To capture high fidelity behavior, the size of finite element models can be hundreds of thousands if not millions of DOF. MBD Solvers that have been developed for decades are not designed to handle large DOF counts that are typically found in nonlinear FEA models. Instead of passing all FE states directly to the MBD solver the internal FE nodes are condensed down to a few boundary connection nodes which are then seen as GSE states by the MBD solver. This approach requires special treatment of error control of these internal states not seen by the MBD solver for numerical convergence. It also exploits current FE High Performance Computing (HPC) methods and architectures such as multithreaded and distributing parallelization methods, as well as leverage future advances in HPC in helping to reduce the computational costs associated with nonlinear FE.

Discussion on these topics as well as numerical examples from automotive and aerospace industries are provided.