Nonlinear Finite Element Formulation for the Large Displacement Analysis in Multibody System Dynamics

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Abstract

A total Lagrangian finite element formulation for the deformable bodies in multibody mechanical systems that undergo finite relative rotations is developed. The deformable bodies are discretized using finite element methods. The shape functions that are used to describe the displacement field are required to include the rigid body modes that describe only large translational displacements. This does not impose any limitations on the technique because most commonly used shape functions satisfy this requirement. The configuration of an element is defined using four sets of coordinate systems: Body, Element, Intermediate element, Global. The body coordinate system serves as a unique standard for the assembly of the elements forming the deformable body. The element coordinate system is rigidly attached to the element and therefore it translates and rotates with the element. The intermediate element coordinate system, whose axes are initially parallel to the element axes, has an origin which is rigidly attached to the origin of the body coordinate system and is used to conveniently describe the configuration of the element in undeformed state with respect to the body coordinate system. A mixed sets of Cartesian translational and rotational coordinates are used in order to define the location and orientation of the deformable body coordinate system with respect to global inertial frame of reference. The nonlinear dynamic equations of motion developed, for deformable multibody systems that undergo large relative displacements, are expressed in terms of a unique set of time-used. These invariants can be generated for each finite element prior to dynamic analysis. The invariants of the deformable body can be obtained by assembling the invariants of the elements using a standard finite element processor. The nonlinear formulation presented in this paper has been implemented in the general purpose computer program DAMS (Dynamic Analysis of Multibody Systems) that automatically constructs and numerically solves the nonlinear equations of motion of multibody systems consisting of interconnected rigid and deformable bodies. The linearization used in other finite element methods (such as the updated Lagrangian formulation) for describing the large displacements of deformable bodies is also discussed.