ABSTRACT

Name of the Candidate	**Manish Agrawal**
SR Number	**05-07-00-10-12-12-1-10083**
Title of the Thesis	**Efficient Simulation Strategies for Electromechanical Systems, Contact Mechanics and Time Finite Elements, within the Framework of Hybrid Finite Elements**
Research Supervisor	**Prof. C. S. Jog**
Degree registered	**Doctor of Philosophy**
Department	**Mechanical Engineering**
Institute	**Indian Institute of Science, Bangalore**

The purpose of this thesis is to provide robust numerical schemes for various challenging nonlinear large-deformation elasticity problems. The presence of geometric and material nonlinearities poses interesting challenges in the numerical implementation of time finite element methods, multiphysics and contact problems, and it is the goal of this thesis to address these challenges.

It is well known that displacement based elements show overstiff behavior known as 'locking' for a large class of practical problems with thin structures, structures with high curvature, and almost incompressible material. To alleviate the locking problem associated with displacement based elements, shell elements based on mixed formulations and hybrid elements have been proposed in the literature. However, due to the kinematic assumptions involved in the development of shell elements, the applicability of these elements is limited. Hybrid elements, based on two-field variational principle are hexahedral elements, with no kinematic assumptions involved in their development. Further, hybrid elements have been shown to provide excellent coarse mesh accuracy for a large class of problems. In this thesis, we further develop the hybrid finite element method for the following new class of problems:

- Developing a quadratic time finite element method for elastodynamics systems

  For chaotic systems, the quadratic transient time finite element strategy is significantly more efficient and robust as compared to the linear transient scheme. Motivated by this, in the first part of the thesis, we propose a quadratic time finite element strategy for large-deformation elastodynamics systems. The proposed method is a modified time finite element strategy that conserves linear and angular momenta exactly, and energy in an approximate sense, in the fully discrete setting. Further, to obtain good coarse mesh accuracy, the proposed transient strategy is extended to the hybrid element framework.

- Analysis of electromechanical systems

  Due to the strong coupling between electromagnetic and displacement fields, there is a need to develop a robust fully-coupled scheme for modeling electromechanical phenomenon. To achieve this, we present a fully-coupled monolithic numerical scheme for modeling electromechanical systems. Further, in view of the superiority of hybrid elements, we extend our monolithic formulation to the hybrid finite element framework. We perform a consistent linearization of the eddy current and structural equations in the reference configuration to ensure a quadratic rate of convergence.

- Contact analysis using mortar methods

  In the final part of the thesis, we attempt the classical problem of contact between two bodies under the large-deformation elasticity framework. We use mortar elements to satisfy the geometric constraint of non-penetrability, and provide a detailed explanation for using two 2-node linear elements on the edge of a 9-node two-dimensional quadrilateral element for the interpolation of the Lagrangian multiplier. We further propose a new projection technique for enhancing the accuracy of the predicted contact pressure. We then extend the above displacement-based formulation to the hybrid framework so as to be able to model the contact of shell-type as well as 'chunky' geometries efficiently.