Explicit Methods in Quasi-Static Analyses of Rubber-Like Materials

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Abstract

Rubber-like materials are commonly used in various industrial applications. They undergo large deformations and behave as nearly incompressible. When finite element analysis of rubber is carried out using implicit solvers any degree of compressibility can be simulated. However, convergence may become an issue in presence of contacts, complex loading conditions, and nonlinear constitutive models. In such cases explicit solvers can be utilized.

In static finite element formulation using implicit time integration, the convergence is achieved when the system of equilibrium equations is satisfied according to a predetermined tolerance. The equilibrium check results in good accuracy. However, the cost of the analysis may be high due to the formation of the global stiffness matrix. Explicit time integration is much more efficient since it does not require the formation of the stiffness matrix, however many time increments may be needed for good accuracy and due to the critical time step size. For nearly incompressible materials such as rubber, the latter imposes limitation on the value of the bulk modulus. The overall goal of this study is to explore the accuracy and efficiency of the explicit integration in the quasi-static analysis of rubber.

In particular, three boundary value problems are analyzed with both implicit and explicit time integration, and the results are compared to each other. In the first problem, a square plate with a central hole is uniaxially stretched. In the second problem, a rubber plate with a central crack is uniaxially stretched. In the third problem, a rubber disk is compressed. For all problems, the density and the loading velocity are varied in order to determine the transition from quasi-static to dynamic state. Dependence of the predictions and the transition on the compressibility of rubber and the magnitude of the applied load are also analyzed.

The conclusions of the investigation of the explicit time integration applied to the boundary value problems with varying degree of constraints may be used in quasi-static analysis of problems with complex contact and loading conditions.

Keywords: Finite element analysis, Quasi-static, Explicit solver, Implicit solver, Near incompressibility, Rubber.