An adaptive method for history dependent materials

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Introduction

Finite element simulations of bulk forming processes, like extrusion or forging, can fail due to excessive element distortion. The simulation of such a process requires either many re-meshing steps or an Eulerian formulation to overcome this problem. This re-meshing or usage of an Eulerian formulation, requires the mapping or convection of state variables. This can cause inaccuracies for history dependent materials, for instance in hardening plasticity. In this research, a new method is examined which avoids the problems mentioned above.

Methods

To explain the method, it will be divided in three main components and these will be treated seperately below.

The first component of the method is a linear triangular element formulation. It is cost effective and easy to generate on a cloud of nodes by means of Delaunay triangulation. For every increment of a large deformation process, the old triangulation is deleted and a new Delaunay triangulation is performed. Thereby, the nodal connectivity is changing in time during the process, hence avoiding the problem of mesh distortion. The method of alpha shapes is used to retrieve the boundary of the cloud of nodes with sufficient detail.

The second component is a nodal integration scheme of the weak form. Integrating the weak form nodally avoids the problem of mapping state variables in case of triangulations. Furthermore the nodal integration scheme gives good results in incompressibility whereas 'Gaussian' integrated linear triangular elements will show locking behavior in the incompressible limit.

The third componenent is an updated Lagrangian formulation. A Jaumann rate is used to account for stress rotation and a rate of deformation as a measure of strain was chosen. The formulation allows history dependent materials to be used in an adaptive strategy.

Results

To examine the performance of the method, two tests were performed. The first is the non-proportional loading of a piece of metal. The second test is the elasto-plastic deformation of a tapered bar. The tests show that indeed it is possible to use history dependent material models in an adaptive strategy without resorting to mapping or convection algorithms. Secondly the artefact of volumetric locking is absent and to conclude, the computation times for this method are found to be comparable to those of finite elements.

Current point of research is resolving an oscillation related to the case of near incompressibility. Though volumetric locking was not found in the current research, the pressure was found to be oscillating spuriously under certain loading conditions. Future research will focuss on examining and resolving this pressure mode.