8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

CHARACTERISTIC GALERKIN FINITE ELEMENT METHOD WITH MARKER PARTICLE INTEGRATION FOR METAL FORMING

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Key Words: *Eulerian description, Characteristic Galerkin finite element method, Marker particle.*

ABSTRACT

In numerical simulations of metal forming and machining process, robust and accurate computational tool that can deal with extremely large deformation of solid needs to be developed. Lagrangian methodologies, which are usually used to solve large deformation problems of solid structure, encounter numerical difficulties when the motion of large deformation distorts the mesh. To overcome such difficulties, the Eulerian approaches[1] are widely used.

In the Eulerian approach, the computational meshes define the entire domain of interest and remain fixed in space. The meshes do not move with materials and the motion of material is described by the techniques tracking the interface on the fixed mesh such as the volume of fraction (VOF)[2] and level set[3] methods. In these methods, the scalar variable that describes the domain occupied by materials is introduced and the transportation of materials is calculated by solving the advection equation for this variable. Thus the Eulerian approach does not suffer from distortion of mesh. However the transportation of the solution variables should be evaluated by solving the advection equation, which may have a tendency to diffuse in numerical methods.

To track the interface, the marker particle methods such as the Marker And Cell (MAC) method[4] can be used. The marker particle methods are Lagrangian approaches to move massless marker particles distributed in materials and they can capture the interface sharply. In the conventional marker particle method, the marker particles play no role in the evaluations of the governing equation and the transportation of the solution variables is evaluated by solving the advection equation again.

In this paper, a novel approach of the Eulerian finite element scheme using the marker particle for solid is proposed. In this approach, the marker particles are utilized not only for tracking the interface but also in the numerical integration as sampling points. Then the solution variables are defined on the marker particles and their transportation can be evaluated automatically by moving the marker particles along the motion of materials. The material derivatives in the equation of motion are approximated by the

characteristic Galerkin method[5] with the numerical integration by the marker particles. Therefore no advection equation appears and the present approach is expected to exhibit less diffusive properties than the conventional Eulerian method.

The algorithm is split into two calculation phases. One is the mesh phase in which the quation of motion is evaluated by the finite element approximation of velocity field on the Eulerian fixed mesh. The domain integral appearing in the weak form of the equation of motion is evaluated by the numerical integration in which the position of the marker particles is taken as a sampling point

Another calculation phase is the marker one in which the Lagrangian variables defined on marker particles are updated. The velocity and its spatial derivative are calculated by interpolating the velocity field on the finite element mesh. From these values, the Lagrangian variables such as the location of markers and stresses defined on the marker are updated.

Several numerical examples are shown and the numerical properties of the present approach are evaluated.

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