Forging and Extrusion Analysis with LS-DYNA® using 3D Adaptive EFG Method

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Abstract

With the recent improvements in adaptive procedure, adaptive mesh-free method has become an important tool to solve the 3D forging and extrusion problems that usually involve large topology change with severe local deformation. In this paper, the implicit version of 3D adaptive EFG method with emphases on the state variable transfer between successive discretizations is presented, and several problems are used to illustrate the effectiveness of the proposed approach. A massively parallel processing (MPP) of adaptive EFG is implemented for the 3-D analysis, and the scalability test is conducted on the highly deformable inelastic example problems.

Introduction

Adaptive procedure has become an important tool for structural analysis, especially in the problems with large deformation, moving interface, and local behavior, where the optimal mesh dramatically changes during the deformation process. In comparison with the conventional finite element method, the built-in features of mesh-free method, such as the smoothness of the solution, naturally conforming of the approximation, and without the use of an explicit mesh, make mesh-free method to be an attractive alternative numerical technique for nonlinear structure analysis, especially in utilizing the adaptive procedure to achieve the accuracy as well as efficiency[1, 2, 3,].

The transfer of state variables between the successive deformations is crucially important to preserve the accuracy and convergence properties in solving the problems with history-dependent materials. Several important aspects should be considered in the state variable transfer stage, such as the consistency with the constitutive equations, requirement of equilibrium and minimization of the numerical diffusion during the adaptive procedure. Various transfer schemes can be found in the literatures [3, 6] for the adaptive procedure. In this paper, a mesh-free state variable transfer technique is proposed. A local interpolation function is constructed such that the transferred state variables will be kept at the desired accuracy while minimizing the numerical diffusion, especially near the boundary undergoes rapid geometric change.

A graded mesh with different mesh density is desirable in solving large deformation with a strong local behavior. In this paper, the curvature of the boundary, which is calculated from the contact master surface, is adopted as a density indicator for the node distribution near the boundary. The mesh inside the domain is controlled by the specified maximum and minimum of the mesh length. In adaptive mesh-free method, mesh information is used to compute the nodal mass and define the boundary in the initialization phase. During the time stepping, only nodal information is required.

State Variable Transfer

The state variables at nodal and integration points for the new discretization can be interpolated from the old discretization as

$$f(\boldsymbol{x}) = \sum_{I=1} \hat{\Psi}_I(\boldsymbol{x}) f_I \qquad (1)$$

Where $\hat{\psi}(\boldsymbol{x})$ is the local smooth interpolation function, as shown in the Figure 1, which is constructed entirely in terms of arbitrarily placed nodes without the use of any element connectivity in the classical sense [4, 5, 6]. In the implicit simulation, reducing the time step or repeating the previous time step with no load increment is used to avoid the convergence problem and preserve accuracy during the adaptive procedure. A special treatment f is adopted to minimize the effect of the numerical diffusion near the contact boundary.

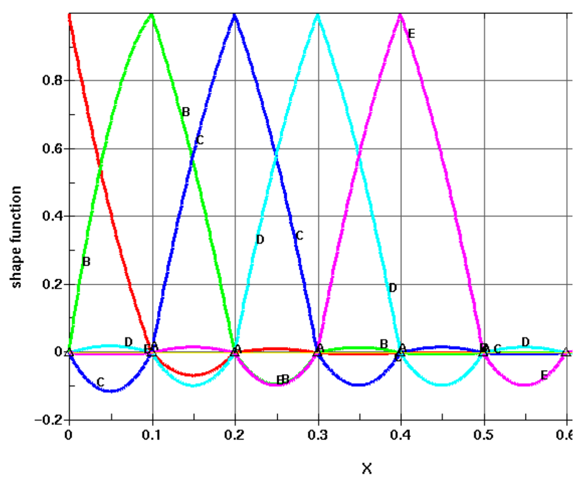


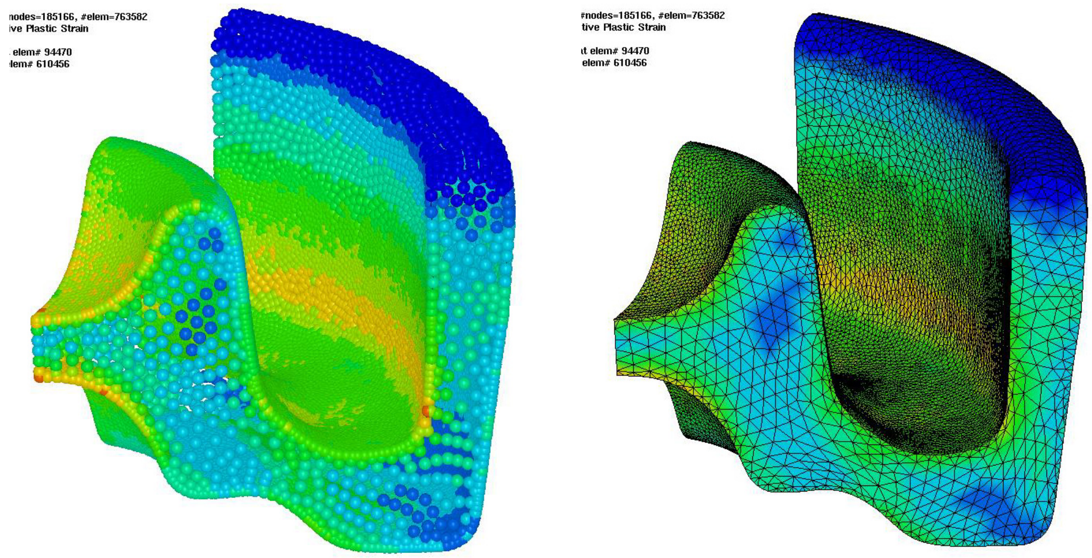
Figure 1 local smooth interpolation function

Numerical Examples

Two examples are analyzed by using the proposed adaptive EFG method. The adaptive procedure is triggered by a given time interval, and the grid distribution is controlled by the specific maximum and minimum grid space. The curved boundary surfaces are discretized with the high density of nodes such that the local behavior can be captured during the simulation.

1 Wheel Forging

The problem is analyzed by the employing 3D EFG adaptive procedure. The distribution of effective plastic strain and the final background mesh in the final deformation are plotted in Figure 2 (a), (b) respectively. During the adaptive procedure, the monotonic property of the internal variables such as the effective plastic strain can be maintained. To save computational time, the parallel version of 3D EFG is also implemented in LS-DYNA® [7]. The MPP scalability for this problem is plotted in the Figure 3.



(a) Contour plot of the effective plastic strain (b) The final background mesh

Figure 2 Wheel forging problem

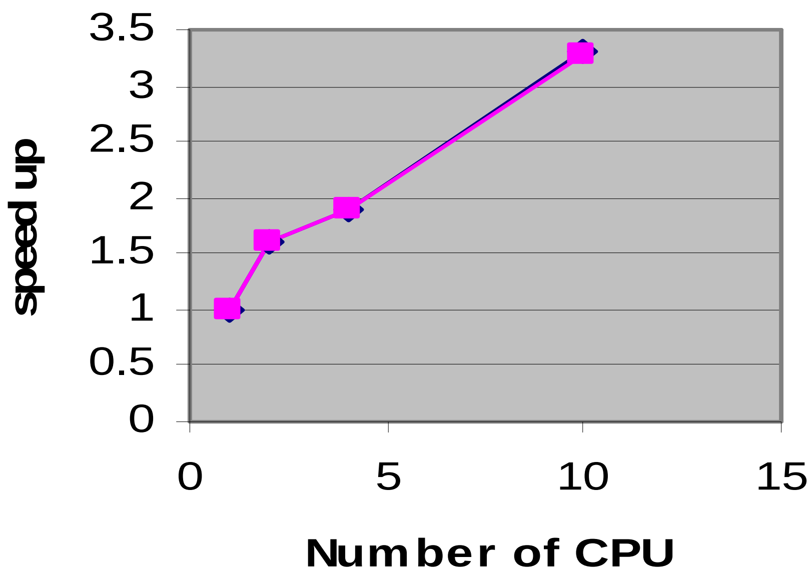
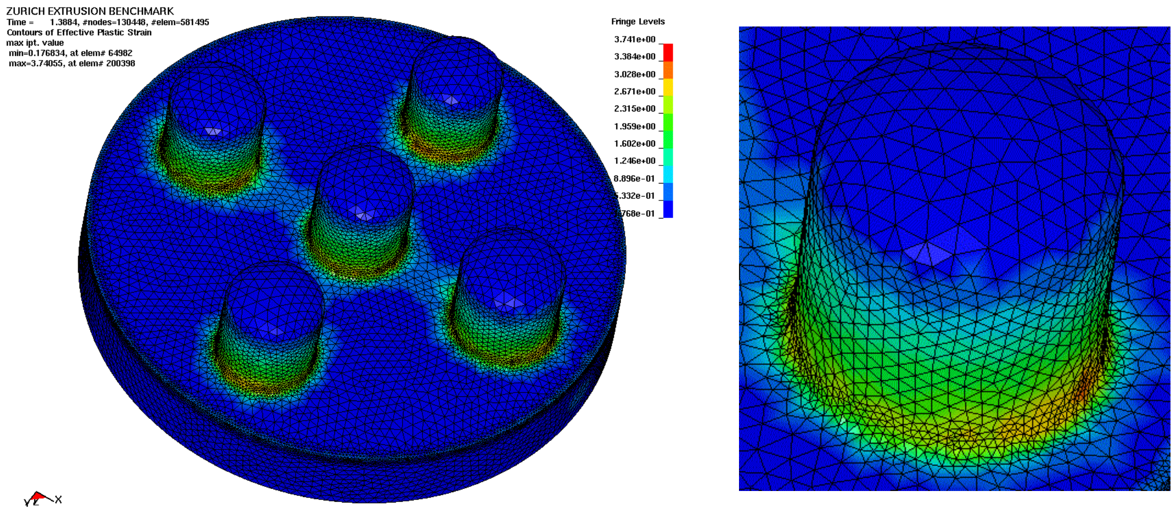


Figure 3 MPP Scalability for 3D EFG adaptivity

2. Extrusion

An extrusion problem with multi-profile is simulated by using adaptive procedure to effectively remesh the domain during the deformation process. The distribution of effective plastic strain and the background mesh near the profile are plotted in Figure 4 (a), (b) respectively. 3D EFG adaptive procedure can successfully capture the local behavior near the profile during the simulation.



(a) Contour plot of the effective plastic strain (b) The background mesh near the profile

Figure 4 Extrusion

Acknowledgements

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