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FURTHER DEVELOPMENT OF THE COMBINED PARTICLE-ELEMENT METHOD FOR HIGH-VELOCITY IMPACT

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When a projectile impacts and penetrates a target at a high velocity the resulting distortions can be very large, resulting in material failure and fragmentation. Although Lagrangian finite elements can provide accurate and efficient computed results for a wide range of applications, they cannot accurately handle the severe distortions that are generated from high-velocity impact. This paper presents recent developments for a new computational approach, called the Combined Particle-Element Method (CPEM). The initial work on the CPEM, for 2D geometry only, was provided by Johnson, Beissel and Gerlach [1].

For this new approach the initial mesh is input as solid finite elements, and then it is put into a meshless-particle structure in the preprocessor. Triangular and quadrilateral elements can be used for 2D geometry, and tetrahedral and hexahedral elements can be used for 3D geometry. The integration points of the original elements are transformed into massless stress points, and the nodes from the original elements carry the mass and accept forces from the stress. The structure is based only on a particle structure, however, with the stress point being a particle that initially has a fixed number of neighbor (particle) mass nodes. In contrast, the existing GPA and SPH algorithms carry all of the variables on all of the nodes.

When the equivalent plastic strain in a stress point is less than a user-specified value (ε_{crit}) a finite-element algorithm (formulated within a particle structure) is used to update the strain rates and strains at the stress point, and to compute forces for the (fixed connectivity) particle nodes. When the equivalent plastic strain in a stress point exceeds ε_{crit} the strain rates are determined from the surrounding (variable connectivity) neighbor nodes (obtained from a search routine) with a Moving Least Squares (MLS) formulation, and the nodal forces are determined from a weak-form formulation. With this approach there is a seamless transition between the element and particle algorithms.

If ε_{crit} is very large the entire computation is based on a finite-element formulation and if $\varepsilon_{crit} = 0$ the entire computation is based on a meshless-particle formulation.

The advantages of such an approach are that the lower-strained particles (stress points) are computed with a fast and accurate finite-element formulation, and the higher-strained particles are computed with a meshless-particle formulation that can handle severe distortions. Furthermore, the meshless-particle algorithm (with MLS strain rates and weak-form forces) is consistent and does not exhibit tensile instabilities. It is also well suited for conversion of finite elements into variable-connectivity meshless particles because it does not require deletion of elements and addition of particles, as required with the existing GPA conversion algorithms [2]. Instead it is simply a branch point based on equivalent plastic strain. The current formulation handles contact between particles in a manner similar to that used for the existing GPA algorithm, but structural contact (element on element) could be added in the future. The CPEM is also well suited for eventual parallelization.

Presentation of some current issues includes the determination of the shape and extent of the weighting functions, the determination of acceptable neighborhoods of particles for the stress points under expanded conditions, determination of preferred neighborhoods of particles for the stress points during the transition of the element algorithm to the particle algorithm, determination of the effects of using different conversion strains (ε_{crit}), and the extension from 2D geometry to 3D geometry.

A group of 2D and 3D examples will be presented, that includes results from the finite-element algorithm only, the meshless-particle algorithm only, and the Combined Particle-Element Method (CPEM) that uses both the element and particle algorithms.

REFERENCES

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