Compatible Finite Element Multi-Material ALE Hydro

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The main ideas of compatible Lagrangian hydro were originally developed in the form of a Finite Volume scheme by Caramana, Shashkov and Burton et al at LANL. The compatible approach is based around two key ideas; a stronger Lagrangian assumption, where corner masses are treated as Lagrangian objects as well as the elements and the enforcement of consistency between the solution of the momentum and internal energy equations. This provides a means of improving total energy conservation and allows greater flexibility in the types of force that can be allowed in a zone. This potentially offers significant benefits in terms of improved accuracy and robustness over traditional staggered grid hydrocode schemes which employ a PdV based internal energy update.

A new compatible finite element Lagrangian hydro method has been developed and implemented in CORVUS, AWE's 2D Arbitrary Lagrangian Eulerian (ALE) code. The new finite element method was developed in preference to the published finite volume schemes for a number of reasons: to see if the fundamental principles of compatible hydro could be translated across to other numerical methods in use in hydrocodes, to facilitate a more direct comparison of the performance of the compatible hydro scheme with the existing finite element scheme in CORVUS and enabled rapid progress to be made as the existing physics in the code could be used immediately.

The key changes required to transform the finite element scheme used for the Lagrangian step in CORVUS to make the scheme into a compatible hydro scheme are; redefinition of the real and area weighted nodal masses and the replacement of the PdV internal energy update with a compatible work update expressed in terms of the corner forces applied in the momentum step and the distance moved by the nodes during the timestep. Once this was established edge artificial viscosities and subzonal pressures were introduce via the introduction of subzonal finite elements with additional nodes this created being treated as non-dynamic points.

The new finite element scheme provides total energy conservation to round off for the Lagrangian step without slide lines. The edge artificial viscosities and sub-zonal pressures that have been introduced through the framework of the compatible hydro scheme provide further improvements in terms of accuracy and robustness for Lagrangian calculations. The energy conservation and symmetry of the slide and void closure algorithms have also been improved by making use of the ideas of compatible hydro.

In order to apply this compatible hydro scheme as the Lagrangian step of a multi-material ALE code a number of problems have had to be overcome. These include how to; calculate the work done on individual material component within multi-material zones where the volume fraction may vary during the Lagrangian step, advect momentum given the new nodal mass definitions and advect the corner masses required by the compatible hydro scheme.

The talk will discuss the details of the compatible finite element Lagrangian scheme, and the extensions required to apply the scheme as the Lagrangian step of a multi-material Arbitrary Lagrangian Eulerian code. This will include recent work on local mesh movement algorithms which attempt to maximise the benefits of the compatible Lagrangian hydro scheme. Test problems and real applications will be presented to demonstrate the benefits and performance of the new method for hydrocode and radiation hydrodynamics applications.