Hierarchical Mixtures in an ICF Code

Alan K. Harrison
Los Alamos National Laboratory, MS T087, P. O. Box 1663, Los Alamos, NM 87545, USA

Flows of interest in ICF problems may span a wide range of length; typically, early-time hydrodynamic instabilities evolve eventually to fully-developed turbulence. To capture the essential features of such flows, it is promising to employ hybrid models that can describe instabilities by multifluid equations and turbulence by a turbulence model. However, in such a model only the fluid dynamics variables are treated differently for low- and high-entropy flows. Other physics packages such as radiation transport and thermonuclear burn have no way to distinguish *a priori* between poorly-mixed "chunk" mixtures and well-stirred "atomic" mixtures. Consequently, important phenomena that depend strongly on mixing structure cannot be modeled well, even with a structure-aware model in the hydrodynamics package. In order for all the physics packages to treat mixtures in a way appropriate to their structure, a representation of that structure must persist outside the hydro package. The representation must account not simply for chunk and atomically mixed cells, but for cells containing arbitrary combinations of both. In an ALE or Eulerian code, it must also be possible to represent unmixed material inside the same cell along with a mixture or combination of mixtures.

We have implemented such a description in an ALE hydro-based ICF code. Data structures describe a mixture hierarchy, for instance, a chunk mixture in which the "chunks" themselves are atomic mixtures. When ALE hydro is active, the division of a mesh cell by reconstructed interfaces is treated as the top level "mixture" in the hierarchy, with chunk and atomic mixtures as the second and third levels. Each element of any pure or mixture material in a mixed cell has its own thermodynamic and material properties, and multiple elements of the same material (e.g., bulk, chunk and atomic Be) may be present in the same cell. Mixing and ALE packages can create, maintain and trim the mixture hierarchy in each cell to correspond appropriately to the subgrid physics being modeled.

This description of matter is coupled to our mix model, a hybrid model based on work by Cranfill. The model describes turbulent flows by a turbulence model, including an energy field, and comparatively ordered mixing flows (hydrodynamic instabilities) by equations for drift velocities as well as a separate energy field. Since the latter flows are typically associated with coherent structures, we model them as producing chunk mixtures, while the turbulent flows create atomic mixtures and shred (atomically mix) preexisting chunks.

This representation of mixtures is useful for several important reasons. First, it allows the code to model phenomena in which the same material may be present in two different conditions (e.g., bulk material and mixed material at a different temperature) in the same cell. Second, it enables us to explicitly track the evolution of material from one state to another within the same cell, to model processes such as chunk dissolution. Third, it provides a more complete description of a mixture, enabling other physics packages to model subgrid processes like transport and energy deposition more faithfully than would be possible based only on cell-averaged properties. Fourth, it makes it possible to model processes that depend critically on the characteristics of the mixture itself (rather than of its constituents).