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Preserving isentropic consistency in multi-fluid systems: basic energy closures and variational evolution equations ERIC HEULHARD DE MONTIGNY, ANTOINE LLOR, CEA, DAM/DIF, 91297 Arpajon cedex, France —
Multi-fluid modeling is required in systems involving numerous entangled mesoscale physical phenomena (bubbles, particles, surface effects, transport, mass-transfer, chemical reactions, turbulence, etc.). It is generally produced by applying some *fluid conditional averaging* to the basic evolution equations (such as mass, momentum, and energy) and closing the ensuing unknown correlations.
However, this procedure does not yield a clear separation between non-dissipative and dissipative correlations, which are critical in understanding multi-fluid behavior and simulation. In particular, many systems follow quasi-isentropic dissipation-free evolution but their simulation appears fragile with respect to numerical errors or approximations as it is basically “living at the edge of stability” [Int. J. Multiphase Flow 103324, 2020].
Hamiltons least action principle is a universal approach to constrain the isentropic self-consistency of evolution equations. It is here applied to multiple velocity systems involving added mass, external and internal turbulence, surface tension, and equal pressure constraints. Combined with Gibbs’ internal energy evolution equations, it yields non-trivial but efficient expressions suited for robust thermodynamically-consistent simulations.

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