Calculations of the Single-Mode Rayleigh-Taylor Instability: RAGE and FLAG Hydrocode Comparisons

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The Rayleigh-Taylor instability (RTI) is a fluid instability that is often encountered in astrophysics, inertial confinement fusion, and in mixing applications. This instability occurs whenever a light fluid is accelerated into a heavy fluid. This fluid configuration is barotropically unstable; that is, perturbations along the interface tend to grow as pressure and density gradients interact to produce vorticity. The instability is named after Lord J. Rayleigh (1883) [1] and G.I. Taylor (1950) [2].

Because of the RTI importance in many applications and because it has been widely studied, the RTI serves as a good test case for comparing the RAGE and FLAG hydrocodes. The goals of this comparative study are to assess and document the codes' ability and identify areas for code improvements. Although the two codes are designed under different philosophies, their designed intended applications overlap enough to allow for designing cross-code comparisons.

Both the RAGE and FLAG codes solve the compressible Euler equations for multi-materials. However, the codes are different in their approach to solve the equations. RAGE is an Eulerian code with adaptive mesh refinement and employs a high-resolution Godunov scheme [3]. FLAG is an arbitrary Lagrangian-Eulerian (ALE) code with an Eulerian mesh remap capability [4].

Several computations of the single-mode RTI of two ideal gases with density ratio 2:1 have been performed for a variety of numerical parameters. These parameters have included advection schemes for RAGE, mesh strategies for FLAG, and interface treatments for both RAGE and FLAG. This investigation study reported in [5] has shown (1) that both RAGE and FLAG calculations of the RTI are similar in mixing width (interface growth) development, and (2) that the use of high-resolution advection schemes and sharper interface treatments in both hydrocodes produce smaller structures in the flow. Out of all the calculations, the RAGE results using Van Leer as the slope limiter and the interface-capturing method with interface preserver have been found to most resemble the FLAG results when run on a mesh aligned with the initial perturbation and using second-order piecewise linear interface reconstruction LVIRA, as shown in the plots of the density contours and vorticity in Fig. 1. The interface growth metric plotted in Fig. 2 at early times compares well with linear theory. Other metrics such as the surface density and circulation have been considered in [5] to better reflect differences in interface area and symmetry issues, respectively.

This study has identified areas where code improvements are to be considered in the future. In particular, symmetry issues have been observed at later times with both codes using interface reconstruction [5]. In future work, other metrics and image analysis may be developed to better discern the flow structure differences and estimate the manifestation of numerical surface tension and other numerical phenomena that are generated during interface reconstruction.

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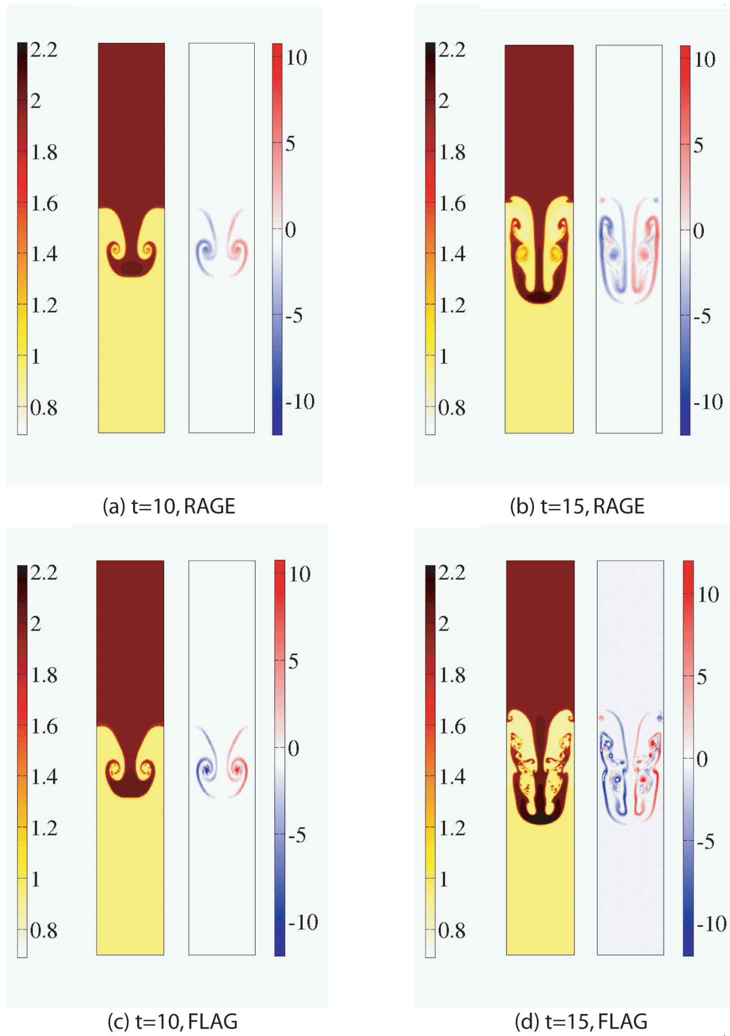

Fig. 1.
Density contours (left) and vorticity contours (right) computed with RAGE and FLAG at times t = 10 and 15.

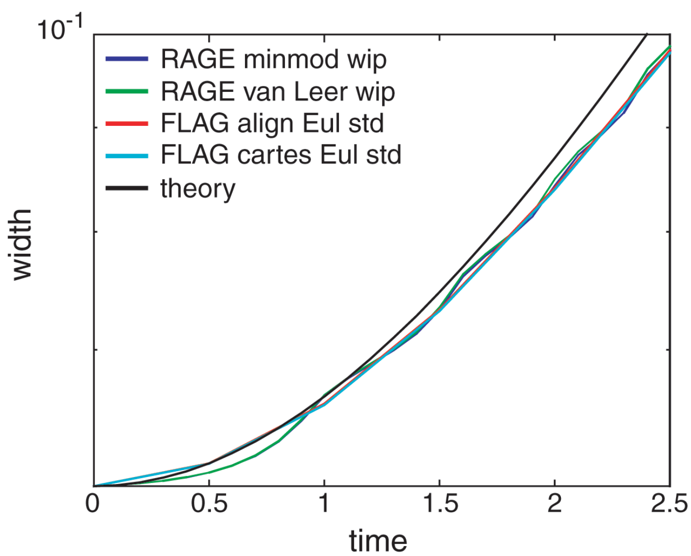

Fig. 2.
Interface growth vs time at early times computed with RAGE and FLAG and compared to linear theory. RAGE computations are performed using two slope limiters (minmod and Van Leer) with the interface preserver option. FLAG computations are performed on a Cartesian mesh and on mesh aligned with the initial interface perturbation in an Eulerian mode with interface reconstruction.