On the Role of Initial Deposition of Baroclinic Vorticity in Richtmeyer-Meshkov Instability

Balu Nadiga, CCS-2

Impulsive acceleration of an interface separating two fluids of different densities, as due to the passage of a shock wave, can lead to amplification of interfacial perturbations in a process termed Richtmeyer-Meshkov instability (RMI) (e.g., [1]). Since this instability mechanism has been recognized as playing a fundamental role in a wide array of natural and manmade phenomena, ranging from stellar evolution to supersonic combustion to inertial-confinement fusion, LANL has a keen interest in the study and description of RMI.

While it has long been recognized that the basic mechanism for the amplification of perturbations is the initial baroclinic deposition of vorticity (resulting from a misalignment of the density and pressure gradients), it is only recently that measurement and analysis of RMI at LANL have highlighted the importance of this mechanism in determining mixing and its characteristics (Fig. 1, [2]).

In this work, we consider a minimal description based on the initial baroclinic deposition of vorticity to describe some of the salient aspects of RMI (necessarily incompletely). For example, Fig. 2 shows the typical evolution of a cylinder of heavy gas. In this case, the initial deposition of baroclinic vorticity is such that there is no secondary instability. In Fig. 3, however, the initial deposition is such that secondary instabilities arise in the course of the evolution. In both these cases, however, the velocity field stretches and folds the density field and increases the power at higher wave numbers, a salient mechanism associated with mixing. Being an inherently unsteady phenomenon, the scalar variance initially grows due to the stretching and folding of the interface, after which diffusive effects lead to its decay. (The time to reach the peak depends on the details of the setup and could be shorter or longer than the reshock time.) Figure 4 shows the evolution of the power spectral density (as a function of wave number) of the density field increasing from left to right with time. In other studies, we are considering the influence of the subsequent subdominant production of baroclinic vorticity.

From a different point of view, the deformation of the interface in any of the above realizations of RMI constitutes a free-boundary evolution problem. Other instances of free-boundary evolution in problems of importance include solidification (dendritic growth, casting) and viscous fingering. There is a project underway at the Laboratory to develop minimal descriptions of the complex shapes that arise in these cases of unstable and nonequilibrium free-boundary evolution processes [3]. The present computational framework is an ideal testbed for this project and will be used to test, verify, and further develop such minimal descriptions of complex shapes.

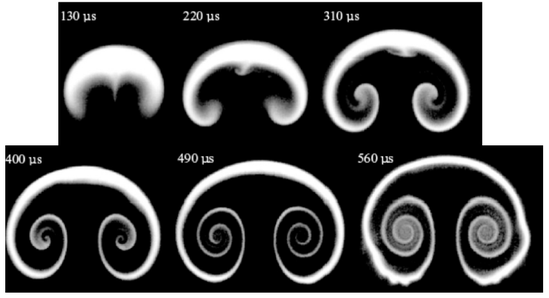


Fig. 1. Experimental measurements of heavy gas concentration in Richtmeyer-Meshkov instability. Figure (adapted) from [2]. Such measurements have highlighted the importance of the initial deposition of baroclinic vorticity on the ensuing mixing.

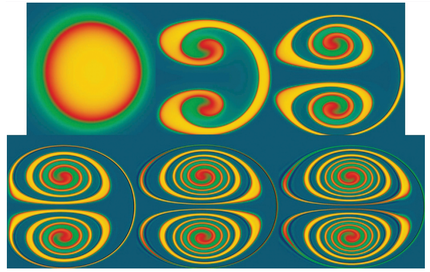


Fig. 2. The rollup of a cylinder of heavy fluid in a numerical setup of Richtmeyer-Meshkov instability that retains only the initial deposition of baroclinic vorticity. In this case the initial deposition is such that no secondary instabilities develop.

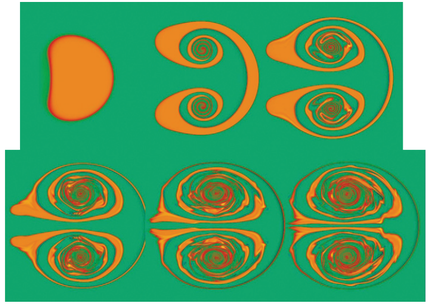
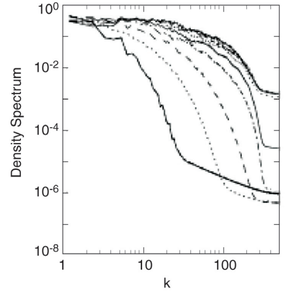


Fig. 3. In a setup similar to that in Figure 2, secondary instabilities are seen to develop (seen in the breakup of the initial spiral rollup) if the magnitude of the initial deposition is higher.

For further information contact Balu Nadiga at balu@lanl.gov.

[1] M. Brouillette, *Ann. Rev. Fluid Mech.* **34,** 445-468 (2002).
[2] C. Tomkins et al., *J. Fluid Mech.* **611,** 131-150 (2008).
[3] M. Mineev, Minimal Descriptions of Complex Shapes, LDRD 20070483ER (2007). LA-UR-NEEDED



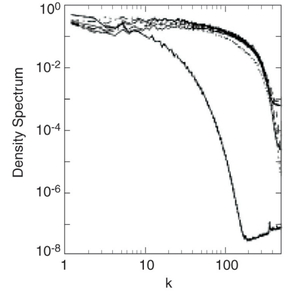


Fig. 4. Power spectral density against wave number for cases in Fig. 2 and Fig. 3 shows that in this unsteady problem, the stretching and folding of the interface by the velocity field increases the variance in the density field, setting the stage for further diffusive mixing.

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