Physics of a Re-shocked Three-Dimensional Multimode Richtmyer-Meshkov Turbulent Layer

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This paper presents a numerical study of a re-shocked turbulent mixing layer using high-order accurate Implicit Large-Eddy-Simulations (ILES). Two specific initial perturbation power spectra are examined: (i) a narrowband high wavenumber perturbation (a constant power spectrum); and (ii) a broadband perturbation having a power spectrum $P=Ck^{-2}$ (typical of an ICF capsule). The first shock is modelled as a velocity impulse, and the initial mixing layer is allowed to develop to a self-similar state with reference to prior results [1]. Once a self-similar state is achieved (Fig. 1), the layer is re-shocked and evolves to a new self-similar state which is significantly different from the original mixing layer (Fig. 1).

. The results are compared to existing theoretical approaches, and the broadband theory of Youngs [2] is extended to predict the behaviour of a re-shocked broadband mixing layer formed initially from a shock interacting with a broadband instability integrated with the ideas of Brouillette and Sturtevant [3]. If $P\sim k^m$ before the first shock then for the linear long wavelength modes before the re-shock $P\sim k^{m+2}$. Then according to the broadband theory the growth rate exponent (width=$W\sim t^\theta$) should change from $\theta = \frac{2}{m+5}$ (first shock) to $\theta = \frac{2}{m+7}$ (re-shock).

Comparisons with the model show very good agreement with the simulation results (Fig. 2), especially in the prediction of the post re-shock asymptotic growth rates (θ=0.36 for the simulation, θ=0.4 from the model) and turbulent kinetic energy decay rate (based on self-similar assumptions). Additional statistics will be presented as several other observations have been made. In brief, re-shock causes a decrease in the degree of molecular mixing for the narrowband layer, but a significant increase for the broadband initial perturbation. The mixing parameters for the broadband and narrowband are observed to be very similar post-reshock, however, the growth rate exponent for the mixing layer width is higher in the broadband case, indicating that the re-shocked layer still has a dependence (although weakened) on the initial conditions.

References:
[1] B. Thornber, D. Drikakis, D.L. Youngs and R.J.R. Williams, submitted to J. Fluid Mechanics (2009).
[2] D.L. Youngs, in Proceedings of the International Workshop on the Physics of Compressible Turbulent Mixing 9 (2004), available online at: http://www.iwpctm.org/.
[3] [M. Brouillette and B. Sturtevant, Physica D 37, 248 (1989)

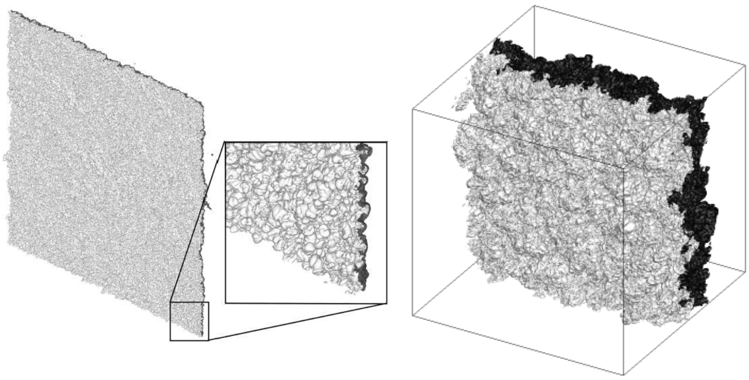

Fig. 1: The self-similar broadband turbulent layer prior to re-shock (left) and after re-shocked (right)

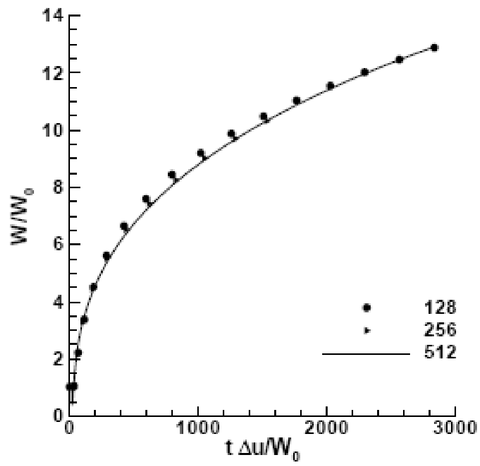

Fig. 2: Evolution of the re-shocked integral width versus time for the broadband mixing layer and for different grid resolutions (θ=0.362 for the 512 case).

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