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Complex Flow Image Velocimetry in Shock Instabilities with Fractal Boundaries

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We use an advanced version of Correlation Particle Image Velocimetry used in surface flows $SFIV$ [1,2] in order to analyze the complex patterns due to the basic instabilities and boundary conditions, and to relate the production and detection of vortices, advected by fast flows with cores of low pressure. These coincide with the 3D lines of strong vorticity or helicity. For example in fast flowing rivers or laboratory experiments of environmental hydraulics [3] or shocks in compressible mixing [4]. The mixing fronts interacts with a density interface producing positive or negative baroclinic structures with varying turbulent cascades[5]. LIF Images of the thickness of the mixing zone at the centre of a shock tube, allow us to perform Multi-Fractal analysis on the evolution of the interfaces [6,7]. The interactions of the pressure fronts with balloons filled with various density gas also allow a wide range of initial conditions. In the same way, using wakes of fractal grids also modify the cascade proceses[7,8]. The three-dimensional mixing zone, its thickness and topology are important experimental measurements. The three basic cases are: when the shock wave passes from a heavy gas to a light one; from a gas to another of similar densities and from a light gas to a heavy one.

We consider body forces and the effect of Baroclinic production of vorticity [5]. The Lagrangian statistics and the characterization of the topology used in SFIV analysis [1,2] is based on the Okubo-Weiss criterion which is an approximate method of partitioning the topologically distinct regions, based on the relative values of

$$Q(x, y) = s(x, y)^2 - \omega(x, y)^2$$

with $s(x, y)$ the local shear, and $\omega(x, y)$ the local vorticity, which is obtained using DigiFlow [4] in real, or Fourier space. In order to evaluate the scale to scale transfer of energy, vorticity and helicity; descriptors of great importance in complex flow processes and intermittency, the data from numerical simulations[5,7] are compared with laboratory experiments [8] in different types (2D-3D) of the turbulence cascade, using models of relative scaling exponents which are estimated as functions of the fractal dimension, D and the spectral slope b. Numerical simulations of Multi-Fractal grids are performed through OpenFoam or incompact3d software; using either direct numerical simulation (DNS) or Large Eddy Simulation (LES)[9].

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