Shock induced baroclinic density-pressure spherical instabilities and mixing

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Abstract

The topological secondary flows produced when a pressure shock tube plane front interacts with a spherical density interface produce different types of turbulent cascades when baroclinic vorticity production changes sign. A set of experiments performed at the large Shock Tube of IUSTI in Marseille [1] the production and detection of vortices, advected by the fast flow with the cores of low pressure were coupled with the study of a shock-induced Richtmyer-Meshkov instability mixing. A powerful CO2 laser, using three detectors during the same run, through three different directions of the test section, for the simultaneous thickness measurement of the mixing zone at the centre of a square-cross-section shock tube, allow us to perform Fractal analysis on the flows [7,8], the interactions of the pressure fronts with balloons filled with different density gas allow a wide range of initial conditions. The three-dimensional mixing zone, its thickness and topology are important experimental measurements. The three cases 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, are investigated for different incident shock wave Mach numbers. It is shown that the thickness of the mixing zone is not constant along the shock tube cross-section, and the measurement of the Atwood number and the fractal dimension of the mixing zone are not linear with the incident shock wave Mach number. Experiments undertaken with low Atwood numbers are used to define a membrane-induced minimum mixing thickness, *Lo*, deone thickness evolution law with time

is. The results are found to produce with CIV velocity and vorticity plots used to calculate spatial correlations intermittency and spectra [3]. The dominant vortices can be studied as they interact, merge or break up. Multifractal spectra and relative scaling exponents are estimated to find empirical scaling exponents related to mixing [2-5]. From the transport equations for velocity and density fluctuations in homogenous turbulence for a zero mean flow (In the moving frame of reference)[6]. Retaining the fluctuations (induced by turbulence) (using $q = u'^2$) and ρ the density, a acceleration, ϵ the dissipation:

$$\frac{\partial u'^2/2}{\partial t} + \overline{w'\frac{\partial u'^2/2}{\partial z}} = -\frac{a}{\rho}\overline{\rho' w'} - \epsilon \quad ,$$

$$\frac{\partial \rho'^2/2}{\partial t} + \overline{w'\frac{\partial \rho'^2/2}{\partial z}} = -\overline{\rho' w'}\frac{\partial \overline{\rho}}{\partial z} - \chi \quad ,$$

$$\frac{\partial \overline{\rho' w'}}{\partial t} + \overline{w'\frac{\partial \rho' w'}{\partial z}} = -\frac{a}{\rho}\overline{\rho'^2} - \overline{w'^2}\frac{\partial \overline{\rho}}{\partial z} -$$

$$\frac{1}{\rho}\overline{\rho'\frac{\partial p'}{\partial x}} - (\kappa + \nu)\overline{\frac{\partial w'}{\partial x_j}\frac{\partial \rho'}{\partial x_j}} \quad ,$$

If the small scale turbulence is quasi-stationary, and the production of turbulence is due to the velocity fluctuations induced by the shock at the interface [7,8]. The term χ is the diffusive dissipation term. $-\frac{a}{\rho}\ \overline{\rho'\ w'}$ is the accelerated dissipation of turbulence, indicating mixing. In the flow L_o, L_b and L_t, are Ozmidov and Buoyancy scales so:

$$\frac{w'}{\epsilon}\frac{\partial u'^2/2}{\partial z} = -\frac{L_b L_t}{L_o^2}\frac{\overline{\rho' w'}}{\rho'\ w'} - 1 \quad ,$$

Is a very helpful parameter space to plot the evolution of fluxes as molecular mixing takes place, with different types of baroclinic production [9-11]. The use of fast reactive indicators could provide visual indication of the complexity of shocks, allowing to measure complex surface velocity fields in compressible flows in 3D flow-boundary interactions. [12-14]

Keywords: Shock tube flows, Baroclinic Vorticity, Compressible Turbulence.

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