Simulation of Multi-Material Compressible Flows with Interfaces

Samuel KOKH, DEN/DANS/DM2S/SFME/LETR, CEA Saclay

We present recent contributions to the simulation of multi-material compressible flows with sharp interfaces. The common ground model of these works is the two-component five-equation model presented in [1]. This model provides a numerical mixture model that is consistent with sharp interface flows when one assume both pressure and velocity to be continuous across the interface.

Within this framework each material is provided with an equation of state $(\rho_k, P_k) \mapsto (\rho_k\varepsilon_k)(rho_k, P_k)$, where ρ_k, P_k and ε_k are respectively the density, pressure and specific internal energy of material $k = 0, 1$. We consider an abstract parameter Z that takes the value 1 (resp. 0) in fluid 1 (resp. 0) et let us note the mass fraction y of fluid 1. We define the global density and internal energy of the two-material medium by $\rho = Z\rho_1 + (1-Z)\rho_0$, $\rho\varepsilon = Z\rho_1\varepsilon_1 + (1-Z)\rho_0\varepsilon_0$ and $Y = Z\rho_1/\rho$. For one-dimensional problems, the model reads

$$\begin{cases} (\rho\mathbf{W})_t + \mathbf{F}(\rho\mathbf{W}, Z)_x = 0 \\ Z_t + uZ_x = 0, \end{cases} \quad \begin{cases} \rho\mathbf{W} = [\rho y, \rho, \rho u, \rho\varepsilon + \rho u^2/2]^T \\ \mathbf{F}(\mathbf{W}) = [\rho y u, \rho u, \rho u^2 + P, (\rho\varepsilon + \rho u^2/2 + P)u]^T \end{cases} \tag{1}$$

where P is the solution of $\rho\varepsilon = Z(\rho_1\varepsilon_1)(\rho_1, P) + (1-Z)(\rho_0\varepsilon_0)(\rho_0, P)$. A dedicated numerical strategy for cartesian meshes that preserves very sharp interfaces without any interface reconstruction process has been proposed in [5]. This numerical scheme is based on a two-step Lagrange-Remap discretization and the anti-diffusive transport technique of [3]. This work has been enhanced for the past years by several collaborations and collective achievements.

First, an implementation on a GPU computing platform of a classical upwind Lagrange-Remap discretization for (1) has been achieved in a joint work with V. Michel (ENSIMAG, Grenoble) and A. Geay (CEA DEN/DANS/DM2S/SFME/LGLS). This work allowed to run interface/shock interaction tests with a 10^9-cell mesh. Then, several means to improve the accuracy of the scheme for non-linear waves while preserving the anti-diffusive interface discretization have been investigated by the CEMRACS 2010 SIMCAPIAD Team. This research group was composed by: M. Billaud-Friess (CELIA, Bordeaux 1 Univ.), B. Boutin (IRMAR, Rennes 1 Univ.), F. Caetano (Paris-Sud Univ.), G. Faccanoni (IMATH, Sud Toulon-Var Univ.), F. Lagoutière (Paris-Sud Univ.), S. Kokh and L. Navoret (Paris Descartes Univ.). Finally, a joint work with M. Billaud proposes an extension of the five-equation model (1) and the anti-diffusive scheme of [5] for simulating flows with an arbitrary number of materials separated by sharp interfaces based on discretization techniques introduced in [4].

Références

[1] Allaire, Clerce and Kokh, *A Five-Equation Model for the Simulation of Interfaces between Compressible Fluids*, JCP (2002), pp. 577–616.

[2] Billaud-Friess, Boutin, Caetano, Faccanoni, Kokh, Lagoutière and Navoret *A Second Order Anti-Diffusive Lagrange-Remap Scheme*, submitted to the proceedings of the CEMRACS 2010.

[3] Després and Lagoutière, *Un schéma non linéaire anti-dissipatif pour l'équation d'advection linaire*, C. R. Acad. Sci., Paris, Sér. I (1999), pp. 939–944.

[4] Jaouen and Lagoutière, *Numerical transport of an arbitrary number of components* , Comp. Meth. in Appl. Mech. and Eng. (2007), pp. 3127–3140.

[5] Kokh and Lagoutière, *An Anti-Diffusive Numerical Scheme for the Simulation of Interfaces between Compressible Fluids by Means of a Five-Equation Model*, JCP (2010), pp. 2773–2809.

Samuel KOKH, DEN/DANS/DM2S/SFME/LETR, CEA Saclay, 91191 Gif sur Yvette CEDEX
`samuel.kokh@cea.fr`