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On the simulation of aerated flows

One of the challenges in Computational Fluid Dynamics (CFD) is to determine efforts exerted by waves on structures, especially coastal structures. The flows associated with wave impact can be quite complicated. In particular, wave breaking can lead to flows that cannot be described by usual models like, e.g., the free-surface Euler or Navier–Stokes equations.

In a free-surface model, the boundary between the gas (air) and the liquid (water) is a surface. The liquid flow is assumed to be incompressible, while the gas is represented by a media, above the liquid, in which the pressure is constant (the atmospheric pressure in general). Such a description is known to be valid for calculating the propagation in the open sea of waves with moderate amplitude, which do not break. Clearly it is not satisfactory when waves either break or hit coastal structures like offshore platforms, jetties, piers, breakwaters, etc.

Our goal is to investigate a relatively simple two-fluid model that can handle breaking waves. It belongs to the family of averaged models and reads as follows:

$$(\alpha^+\rho^+)_t + \mathrm{div}(\alpha^+\rho^+\mathrm{u}) = 0, \tag{1}$$

$$(\alpha^-\rho^-)_t + \mathrm{div}(\alpha^-\rho^-\mathrm{u}) = 0, \tag{2}$$

$$(\rho\mathrm{u})_t + \mathrm{div}(\rho\mathrm{u}\otimes\mathrm{u} + p\mathrm{I}) = \rho\mathrm{g}, \tag{3}$$

$$(\rho E)_t + \mathrm{div}(\rho H\mathrm{u}) = \rho\mathrm{g}\cdot\mathrm{u}, \tag{4}$$

where the superscripts $\pm$ are used to denote liquid and gas respectively. In this model we show that the pressure p is given as a function of three parameters, namely $\alpha \equiv \alpha^+ - \alpha^-$, ρ and e:

$$p = \mathcal{P}(\alpha, \rho, e). \tag{5}$$