SIMULATION OF SSVARTS

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Self-Similar Variable Acceleration Rayleigh–Taylor (SSVART) flows are a potentially important reference for modeling of turbulent buoyancy driven mixing layers. Llor[4] defines a SSVART to have gravitational forcing $g(t)$ that varies according to $g \propto t^n$ over $t > 0$ when $n > -2$, or $g \propto (-t)^n$ over $t < 0$ when $n < -2$. Within this definition there is the possibility of the standard RT flow $(n = 0)$, increasing $g(t)$, and also a decreasing $g(t)$ when $-2 < n < 0$. Simulations of SSVARTs with $n \geq -1$ have been carried out before[5]. The self-similar growth of a RT mixing layer with time t is given by $L = \alpha_n A g(t) t^2$, where L is the height of the mixing layer, A is the Atwood number and α_n is the growth coefficient. Determination of α_0 and its dependence on initial conditions is discussed extensively by the Alpha-Group collaboration[6].

Growth of the mixing layer can display self-similarity within the range of practically all n values. However, there are limits to the similarity which can be found from the buoyancy-drag equation[7], that yields $\alpha_n = \alpha_0(1+n/2)^{-1}(1+n/(2-\theta))^{-1}$. There are two poles, one occuring at $n = -2$ when the forcing term becomes infinite, and one when the growth rate matches that of a Richtmyer–Meshkov (RM) mixing layer at $n = -2+\theta$ (where in experiments $\theta \approx 1/3$, while simulations have $\theta \approx 1/4$). Between the poles self-similarity is dominated by the faster RM growth. When $n \to -2$ for $n < 0$ there is an increasing dependence on the initial structure.

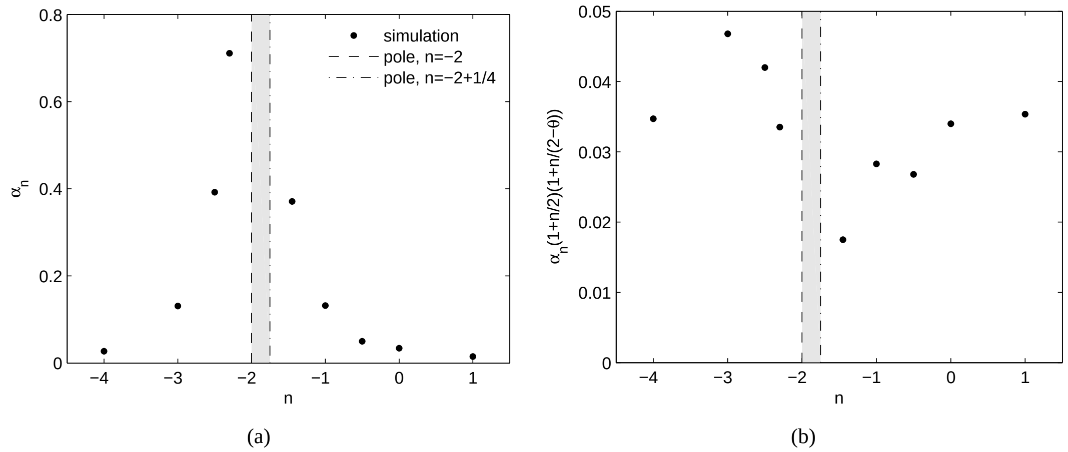

Figure 1. Variation of α_n with n, showing RM dominated region between the two poles.

Simulations can provide a useful database of results for flow modelling because of the ability to acquire comprehensive statistics and measurements. Along with this, the flexibility brought by an accurate description of the conditions is particularly important when specifying $g(t)$. The code used for this work solves the incompressible Navier–Stokes equation with a second-order finite volume formulation and a multi-grid method is used to solve the Poisson equation. As standard the simulations will be carried out using $512^2 \times 1024$ grid points (double that of the Alpha-Group[6]), but it is also possible to solve problems with up to $2048^2 \times 4096$ points.

Currently we have preliminary results over a range of n values from which it is possible to derive some basic statistics. The flow is self-similar when normalised measurements become constant with time and as a result the coefficient α_n will also be constant. Each of the simulations display self-similarity to a varying degree of accuracy which reduces when nearing the poles. Figure 1(a) shows a large variation in α_n particularly in the vicinity of the poles where its value increases quickly as expected, but scaling with the buoyancy-drag equation in figure 1(b) improves the collapse of the results. As with α_n other statistics are expected to vary substantially with n because the energy transfers are strongly affected by the varying potential energy reservoir that is feeding the flow. For example when approaching the singularity with $n < -2$ the flow has increasing $g(t)$ and so becomes overloaded with directed energy, while it is expected that the energy transfer to turbulence will not keep up. Alternatively, when the singularity is approached with $n > -2$, α_n becomes large to compensate for a rapidly decaying gravity force. The conditions in such flows are nearing that of a RM mixing layer and it is expected that there will be a corresponding change in the flow properties.

At the time of the workshop we will present full histories of statistics including input, directed and turbulent energies, along with the turbulence statistics. It may also be possible to use structure detection to separate the turbulence and large scale flow features of the mixing layer[8]. Current simulations will be extended to higher Atwood number, where growth is expected to become asymmetric, just as for the RT and RM cases[7].

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