2-D LARGE EDDY SIMULATION OF LOCK-EXCHANGE GRAVITY CURRENT FLOWS

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Lock-exchange gravity current flows produced by instantaneous release of a heavy fluid are investigated using 2-D Large Eddy Simulation (LES). The model is first validated using the 2D Direct Numerical Simulation (DNS) results of Hartel et al. [1] for the classical lock-exchange gravity current flow in an infinite channel (no lateral walls) with no-slip walls. Very good qualitative (Fig. 1) and quantitative agreement is observed (e.g., front velocity and Reynolds number are predicted within 1%). Then the code is applied to study quantitative and qualitative aspects of the evolution of gravity current flows for the case in which the heavier (lock) fluid is initially situated in between the vertical end wall on the left and the lock barrier and extends over the whole channel depth. All solid boundaries are simulated as no-slip walls. Three different length over depth aspect ratios of initial domain occupied by the heavier fluid are considered (see Table 1) corresponding to the cases studied experimentally by Hacker et al. [2]. It is found that 2D LES is able to capture most of the physics observed in experiments including the evolution of the head and its velocity during the slumping phase, as well as the formation of coherent billow structures at the apex of the head due to Kelvin-Helmholtz instabilities. An example in shown in Fig.2 corresponding to the predicted evolution of current in case B along with the experimental visualizations in [2]. The simulations also allow investigating the evolution and structure of the gravity current during the transition between the slumping phase and the self-similar phase when the bore formed due to reflection at the end wall of the return flow overtakes the front. Our simulations also show (see Fig. 3) that during the similarity phase the front position x_f advances as $t^{2/3}$ (t is the time measured from release) and the front speed decays as $t^{-1/3}$ which is consistent with theory.

Table 1. Details of the lock-exchange cases simulated. Reynolds number $Re = U_f(h/2)/\upsilon$ and Froude number $Fr = U_f/\sqrt{g'h}$ during the slumping phase (constant front velocity).

Case	L/L$_0$	x_o/L$_0$	h/L$_0$	Aspect ratio, $R = h/x_o$	Experiment		Simulation	
					Re	Fr	Re	Fr
A	3.60	0.30	0.20	0.67	7000	0.45±0.01	6655	0.429
B	3.60	0.40	0.40	1.00	19700	0.45±0.01	19552	0.446
C	3.60	0.15	0.267	1.78	11000	0.46±0.01	10200	0.428

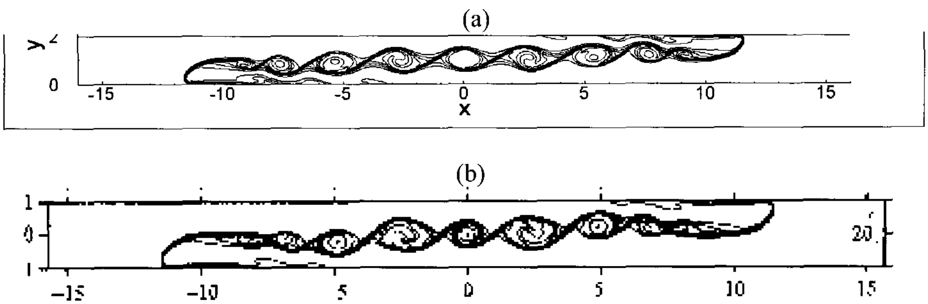

Fig. 1 Density contours corresponding to 2D lock-exchange flow in an infinite channel with no slip walls at a Grashof number of Gr = 1.25 x 10^6. Nondimensional time is t = 20. (a) Flow field of present 2D LES. (b) Flow field of 2D DNS of Hartel et al.

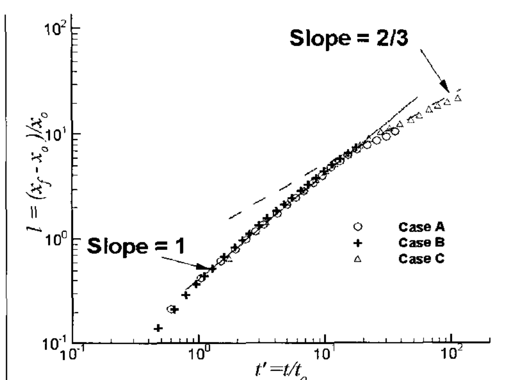

Fig. 3 Front position in log-log scale.

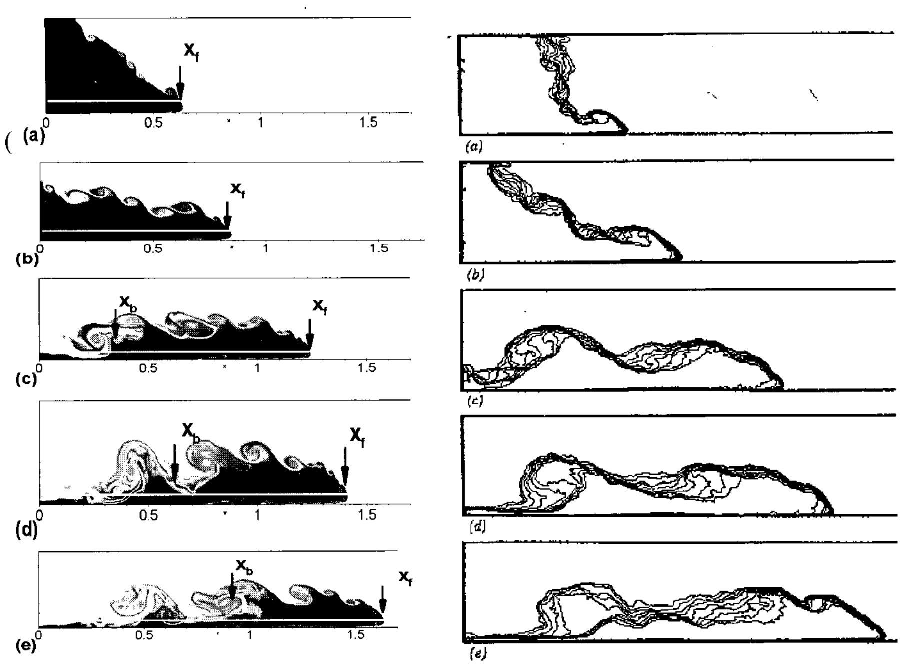

Fig. 2 Evolution of gravity current for case B in [2]. Density contours at subsequent non-dimensional front positions, $l = (x_f - x_o)/x_o$, and simulation times, t; (a) l = 0.60, t=0.9 (b) l = 1.11, t=1.6 (c) l = 2.10, t=3.0 (d) l = 2.56, t=3.6 (e) l = 3.08, t=4.4.

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