LETTERS

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Dislocation glide observed in bimodal convection

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(Received 8 June 1984; accepted 9 August 1984)

Both dislocation climb and glide are known to occur in solid-state physics, but only climb has been observed in dislocation defects (pinches) in convection cells. A search of movies of convection has uncovered observations of dislocation glide in the cross rolls in bimodal convection. The climb also exists with the dislocation moving in a direction opposite of the climb previously observed in convection rolls, i.e., toward long wavelength.

Even though there is now impressive understanding of the equilibration of Rayleigh–Bènard convection in many regions of parameter space,[1] laboratory studies of convection in large-aspect-ratio chambers generally reveal disordered and nonstationary rolls. The disorder arises in part because the rolls curve and meet in a number of dislocations, some looking strikingly like defects in liquid crystals.[2] These dislocations and their motion introduce a migration of the roll pattern and an accompanying change in wavenumber.[3] Even for very long times there is now clear experimental[4,5] and computational evidence[6,7] that defects persist. Gollub and McCarriar,[4] for instance, Fourier-analyzed roll cells in long time experiments and found that rolls align normally to the wall. For a rectangular container, the final shape of the roll pattern involved two dislocations. Thus, dislocations may be in some sense fundamental in convection.

The existence of dislocations has been known for a long time; there are photographs dating back to 1913 by Dauzière.[8] Some attempts have been made to theoretically describe them.[6,7,9] Siggia and Zippelius,[9] in particular, compared numerical experiments of dislocation climb velocity with some results of the laboratory experiments of Whitehead,[5] but there was only a small overlap possible in the physical parameters. However, a universal finding has been that the defects are of the dislocation class and always exhibit climb (along-axis motion) toward the smaller rolls, and never possess glide (across axis) motion unless conditions are specifically set up to strongly favor glide.[7]

Bimodal flows, in the Rayleigh number range of 20 000 to approximately 100 000 and in fluid of Prandtl number 126, can possess dislocations in the primary or secondary rolls. At the present time, nothing is reported of the speed or direction of propagation of these dislocations. From a movie made in 1970 with F. Busse,[10] it was found that defects in

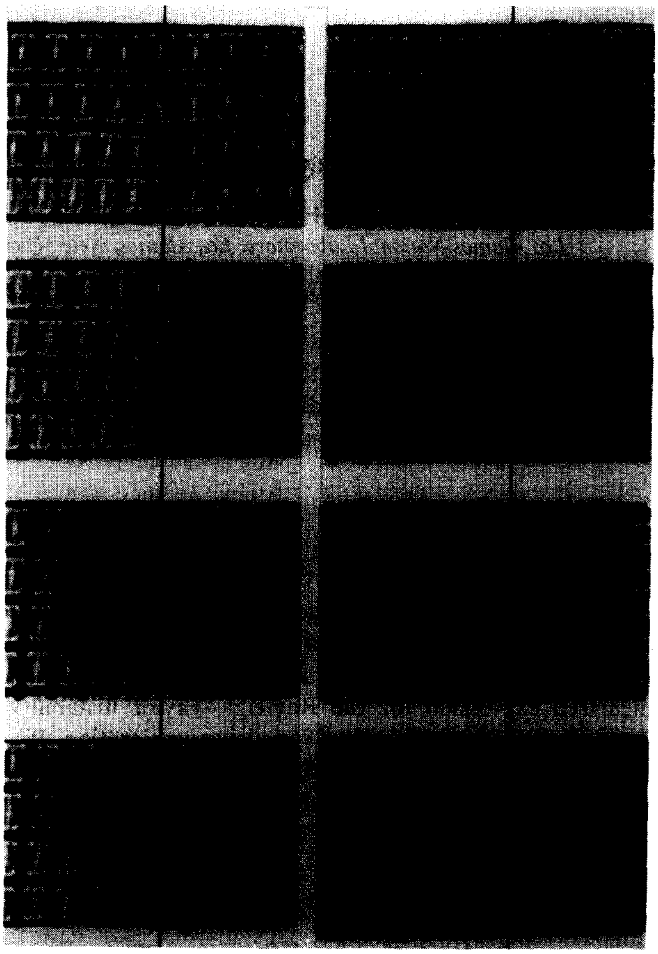

FIG. 1. Shadowgraph of bimodal flow with one dislocation in the cross rolls which, in this photograph, are vertical. The black vertical line has been carefully aligned to be in the same spot with respect to the horizontal coordinate. The dislocation migrates upward and toward the left.

0031-9171/84/102389-02$01.90

rolls in bimodal flows exhibit both climb and glide motion, parallel and perpendicular to the secondary rolls. Figure 1 shows the motion of a dislocation formed at a Rayleigh number of approximately 50 000. The dislocation clearly climbs in a direction opposite to that observed in rolls (i.e., into the long-wavelength direction). It also clearly shows glide motion as it migrates toward the left.

Four other dislocations were observed in the same film and all started from equal and oppositely directed pairs of defects. Three of the four defects had no glide (one did not even move) but one did distinctly have glide. Thus the magnitude of both climb and glide may be sensitive to the presence of dislocations nearby and the large-scale distortion of the cell matrix.

[1] F. H. Busse, Rep. Prog. Phys. **41**, 1929 (1978).

[2] The defects are shown by E. Gauzzelli, E. Guyon, and J. E. Wesfreid, in *Proceedings of the Colloque Pierre Curie*, E.S.P.C.I., Paris, September 1980, edited by N. Boccara (IDSET, Paris, 1981), pp. 455–461. The defects are virtually identical to those in the next reference.

[3] J. A. Whitehead, J. Fluid Mech. **75**, 715 (1976).

[4] J. P. Gollub and A. R. McCarrier, Phys. Rev. A **6**, 3470 (1982).

[5] J. A. Whitehead, Jr., Phys. Fluids **26**, 2899 (1983).

[6] A. C. Newell and J. A. Whitehead, J. Fluid Mech. **38**, 279 (1969); M. C. Cross, Phys. Rev. A **25**, 1065 (1982); Y. Pomeau, S. Zaleski, and P. Manneville, Phys. Rev. A **27**, 2710 (1983).

[7] H. S. Greenside and W. M. Cochran (private communication).

[8] C. Dauzière, C. R. Acad. Sci. **156**, 218 (1913).

[9] E. D. Siggia and Zippelius, Phys. Rev. A **24**, 1036 (1981).

[10] The movie was taken simultaneously with photographs that became Fig. 14 of F. H. Busse and J. A. Whitehead, J. Fluid Mech. **47**, 305 (1971). The defect and hints of glide are visible.

Coherent density gradients in water compressed by a modulated shock wave

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(Received 1 August 1984; accepted 9 August 1984)

A shock wave propagating from liquid metal into water via a corrugated interface produces quasiperiodic perturbations in the compressed water, as determined by shadowgraphy. Theoretical analysis indicates that the shadows are caused by density gradients which occur from the coherent interaction among reverberating pressure waves.

We report experimental and theoretical results on the study of a shocked interface between liquids of different densities. Richtmyer[1] first showed analytically that the usual, linearized expression for the Rayleigh–Taylor instability could be applied to the case of impulsive acceleration. If a two-fluid interface in the X-Y plane, perturbed in the form $a_0 \cos 2\pi x/\lambda$, is accelerated in the Z direction, then the time-dependent amplitude $a(t)$ of the interface ripples having wavelength λ is given by

$$\ddot{a}(t) = Kg(t)a(t)[(\rho_2 - \rho_1)/(\rho_2 + \rho_1)], \qquad (1)$$

where ρ_i are the densities and $g(t)$ is the accleration. Equation (1) applies in the small amplitude approximation, $2\pi a/\lambda \ll 1$. Continuous acceleration causes growth or oscillation in $a(t)$, depending on the sign of $g(t)$. If acceleration is impulsive, then

$$g(t) = U\delta(t) \qquad (2)$$

and

$$\dot{a}(t) = KUa_0[(\rho_2 - \rho_1)/(\rho_2 + \rho_1)]. \qquad (3)$$

Although this expression is an oversimplification for compressible fluid flow, it does show that a rippled interface between fluids of different density is always unstable under shock loading. Meshkov's[2] experiments on shocked interfaces between gases of different molecular weight demonstrated this instability. For gases at one atmosphere pressure and below, the ideal gas equation of state can be used, so the molecular weight determines density, sound velocity, and shock impedance. By contrast, the present work examines the complex flow field in shock-compressed *liquid* contiguous with the perturbed interface. Both Meshkov's work

0031-9171/84/102390-04$01.90