

Stability of oscillatory two-phase Couette flow: theory and experiment

Michael R. King, David T. Leighton, Mark J. McCready
Department of Chemical Engineering
University of Notre Dame
Notre Dame, IN 46556

Abstract

The interfacial instability due to viscosity stratification is studied experimentally in a closed Couette geometry. A vertical interface is formed between two concentric cylinders with density-matched fluids of unequal viscosity. The outer cylinder is rotated with a time-harmonic motion, causing periodic disturbances of the interface. The wavelengths, growth rates, and stability boundaries predicted by linear theory agree well with experimental results. Application of FjØrtoft's inflection point theorem shows the neutral stability curves to be consistent with an internal shear instability occurring in the less viscous phase. Since the standard Floquet theory yields only time-averaged growth rates, the instantaneous behavior of the system is examined numerically, revealing the flow to be simultaneously unstable to a shear mode and interfacial mode. Surprisingly, it is found that interfacial wave amplification is due to the internal disturbance, and a mechanism for wave growth is proposed. This unsteady instability may explain the growth of waves in "transient" process flows, e.g., fluids encountering changing flow geometry. It is also demonstrated that in the long wave limit the problem of steady-plus-oscillatory plate motion is simply additive. This implies that it is possible to use oscillations to stabilize steady waves over a limited range of parameter values, but only when the less viscous phase is adjacent to the moving boundary.