Mixing of a two-layer stratified fluid by a rotating disk

Don L. Boyer

Department of Mechanical and Aerospace Engineering and Environmental Fluid Dynamics Program, Arizona State University, Tempe, AZ 85287-5806 USA

Peter A. Davies

Department of Civil Engineering, The University, Dundee DD1 4HN UK

Yakun Guo

Department of Civil Engineering, The University, Dundee DD1 4HN UK

Received 21-SEP-95
in revised form 08-MAR-96

An experimental investigation is presented on the large-scale motion field and associated mixing of an initially two-layer, equal depth stratified fluid driven by an impulsively-started, rotating disk at the base of the (cylindrical) fluid container. For sufficiently large Reynolds numbers and fixed geometry, the flow is shown to depend on a single parameter, the Richardson number $Ri = g' H / (\omega RT)^2$, where $g'$ is the reduced gravity, $H$ is the depth of each of the fluid layers, and $\omega$ and $RT$ are the disk rotation rate and radius, respectively. For $Ri < 1.5$ the primary mixing mechanism is found to be shear-induced billowing along the primary density interface, with the mixed fluid along this interface being advected into the lower fluid interior by secondary motions. An analysis is advanced to show that the elevation of the interface separating the upper (almost quiescent) layer of constant density from the lower mixed region grows as $[Ri^{-1} (H/RT)^{-1}] \omega t$, where $t$ is the time. The experimental observations are in good agreement with this scaling. The studies reveal that the large-scale secondary motion fields characteristic of this physical system force secondary interfaces, or fronts, to be formed periodically in the lower mixed layer region. These secondary fronts are shown to be relatively weak, with the velocity and density jumps across them being small compared with those across the primary interface.

Copyright (c) 1998 Elsevier Science B.V. All rights reserved.