THE STABILITY OF THE PROPAGATION OF SHARP VOIDAGE FRONTS
IN LIQUID FLUIDIZED BEDS

A. K. Didwania and G. M. Homsy
Department of Chemical Engineering
Stanford University
Stanford, California 94305, U.S.A.

ABSTRACT

Experiments were performed on the propagation and stability of voidage fronts produced by a sudden change in operating conditions. For experiments relatively unaffected by inevitable mal-distribution, the front is stable and propagates in accord with a simple theory. Fronts which are potentially gravitationally unstable were also observed to propagate stably. Linear instability theory, assuming the fluidized mixture to behave as an effective Newtonian fluid, predicts a high degree of instability, in disagreement with experiment. We conclude that the assumption of an effective Newtonian fluid is a poor one.

INTRODUCTION

The propagation and stability of sharp fronts across which voidage varies is a key problem in fluidization. These fronts occur in the context of a sudden change in operating conditions, such as those studied by Slis, et al. (1959), and in the settling of a bed following a decrease in fluidizing velocity. The motion of a bubble through a fluidized bed may also be thought of as the propagation of a front across which there is a (large) variation in voidage. In previous work, El-Kaissy and Homsy (1976), we studied the growth of voidage waves and their relation to the origin of bubbles. In this case, rapid growth of instabilities results in the formation and propagation of voidage fronts in the vertical direction.
It is possible for the front to have jumps in voidage which result in the more dense regions lying above the less dense. We shall refer to this as the "unstable" configuration, as it is potentially gravitationally unstable. The opposite case will be referred to as the "stable" configuration. "Unstable" configurations include the roofs of bubbles, the front following a rapid increase in fluidizing velocity, and the instability waves noted above. The stability of such configurations are of interest in theories of the maximum stable bubble size, which envision the bubble roof becoming unstable, thereby limiting the growth of bubbles by coalescence; see, e.g. Rice and Wilhelm (1958), Clift et al. (1974), and Upson and Pyle (1973). As is well known, it is not possible to make a direct comparison between existing theory and experiments on bubble splitting, since the theory assumes a velocity in the base state which is steady and unidirectional while the flow around a bubble is axisymmetric. Also, the stability of time-dependent phenomena such as voidage waves is difficult to treat in a satisfactory manner.

The objectives of this work then, were (1) to verify a theory of the propagation of voidage fronts in the "stable" configuration, based upon a simplified set of dynamic equations; (2) to observe the details of the motion in the "unstable" case and in this latter case, (3) to compare observed motions with those predicted by linear stability theory.

EXPERIMENTS

Experiments were carried out in a plexiglass column, 30 cm wide \times 180 cm high \times 3.15 cm deep, with uniform flow distribution at the base. Fluidizing water passed through a 30 cm high packed bed section filled with glass beads (0.59 mm diameter) and a few fine wire screens before entering the bed, ensuring flow uniformity in steady flow. However, slight flow maldistribution near the base of the bed can lead to large effects in time-dependent flow, due to "jet effects" caused by the flow manifold below the packed section, especially in the case of a step increase in the fluidizing velocity. In some cases, described below, these phenomena had limited effect on the propagation characteristics, being confined to short times and regions near the distributor. In other cases, they were so severe as to constitute the primary mode of response of the system.

Glass ballotini particles of a narrow size range (0.589-0.417 mm) with dominant diameter 0.59 mm and density 3.99 gm/c.c. were used. The bed height at minimum fluidization was 59.5 cm, and the voidage, $\varepsilon_{mf} = 0.363$. For these conditions, $u_{mf} = 0.73$ cm/s. The range of fluidization velocity investigated was $0 \leq u/u_{mf} \leq 5$ for step decrease in fluidizing velocity and $0 \leq u/u_{mf} \leq 2.0$ for step increase in fluidizing velocity. A step change in the