Kinematic Waves in Steady Flows

In many, nominally steady two-phase flows there is sufficient ambient *noise* or irregularity in the structure, that the inhomogeneity instability analyzed in section (Njm) leads to small amplitude kinematic waves that propagate that structure (see, for example, El-Kaissy and Homsy, 1976). While those structures may be quite irregular and sometimes short-lived, it is often possible to detect their presence by cross-correlating volume fraction measurements at two streamwise locations a short distance apart. For example, Bernier (1982) cross-correlated the outputs from two volume fraction meters $0.108m$ apart in a nominally steady vertical bubbly flow in a $0.102m$ diameter pipe. The cross-correlograms displayed strong peaks that corresponded to velocities, u_{SL}, relative to the liquid that are shown in figure 1. From that figure it is clear that u_{SL} corresponds to the infinitesimal kinematic wave speed calculated from the measured drift flux. This confirms that the structure consists of small amplitude kinematic waves. Similar results were later obtained for solid/liquid mixtures by Kytomaa and Brennen (1990) and others.

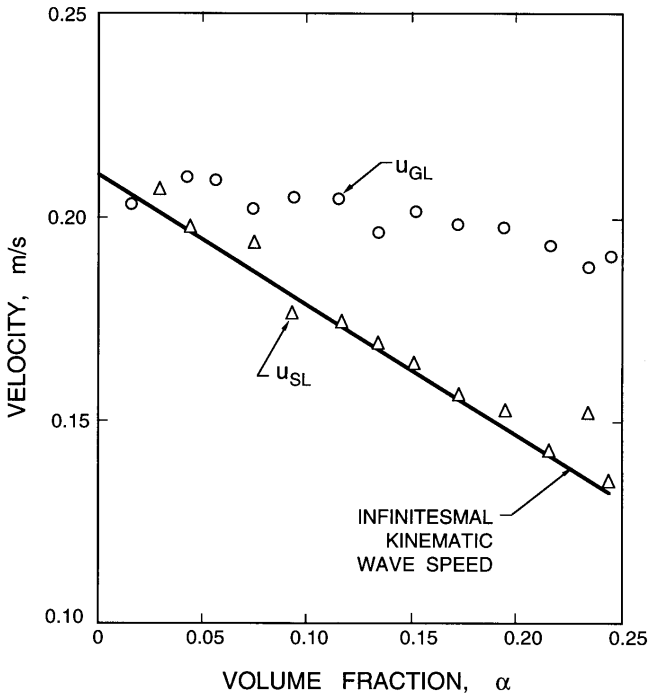

Figure 1: Kinematic wave speeds, u_{SL} ($\triangle$), in nominally steady bubbly flows of an air/water mixture with $j_L = 0.169m/s$ in a vertical, $0.102m$ diameter pipe as obtained from cross-correlograms. Also shown is the speed of infinitesimal kinematic waves (solid line, calculated from the measured drift flux) and the measured bubble velocities relative to the liquid (u_{GL}, $\odot$). Adapted from Bernier (1982).

It is important to note that, in these experiments, the cross-correlation yields the speed of the propagating structure and not the speed of individual bubbles (shown for contrast as u_{GL} in figure 1) because the volume fraction measurement performed was an average over the cross-section and therefore an average over a volume much larger than the individual bubbles. If the probe measuring volume were small relative to the bubble (or disperse phase) size and if the distance between the probes was also small, then the cross-correlation would yield the dispersed phase velocity.