

Effect on Turbulence Stability

The issue of whether particles promote or delay transition to turbulence is somewhat distinct from their effect on developed turbulent flows. Saffman (1962) investigated the effect of dust particles on the stability of parallel flows and showed theoretically that if the relaxation time of the particles, t_u , is small compared with ℓ/U , the characteristic time of the flow, then the dust destabilizes the flow. Conversely if $t_u \gg \ell/U$ the dust stabilizes the flow.

In a somewhat similar investigation of the effect of bubbles on the stability of parallel liquid flows, d'Agostino *et al.* (1997) found that the effect depends on the relative magnitude of the most unstable frequency, ω_m , and the natural frequency of the bubbles, ω_n (see section (Ngj)). When the ratio, $\omega_m/\omega_n \ll 1$, the primary effect of the bubbles is to increase the effective compressibility of the fluid and since increased compressibility causes increased stability, the bubbles are stabilizing. On the other hand, at or near resonance when ω_m/ω_n is of order unity, there are usually bands of frequencies in which the flow is less stable and the bubbles are therefore destabilizing.

In summary, when the response times of the particles or bubbles (both the relaxation time and the natural period of volume oscillation) are short compared with the typical times associated with the fluid motion, the particles simply alter the effective properties of the fluid, its effective density, viscosity and compressibility. It follows that under these circumstances the stability is governed by the effective Reynolds number and effective Mach number. Saffman considered dusty gases at low volume concentrations, α , and low Mach numbers; under those conditions the net effect of the dust is to change the density by $(1 + \alpha\rho_S/\rho_G)$ and the viscosity by $(1 + 2.5\alpha)$. The effective Reynolds number therefore varies like $(1 + \alpha\rho_S/\rho_G)/(1 + 2.5\alpha)$. Since $\rho_S \gg \rho_G$ the effective Reynolds number is increased and the dust is therefore destabilizing. In the case of d'Agostino *et al.* the primary effect of the bubbles (when $\omega_m \gg \omega_n$) is to change the compressibility of the mixture. Since such a change is stabilizing in single phase flow, the result is that the bubbles tend to stabilize the flow.

On the other hand when the response times are comparable with or greater than the typical times associated with the fluid motion, the particles will not follow the motions of the continuous phase. The disturbances caused by this relative motion will tend to generate unsteady motions and promote instability in the continuous phase.