Surprising responses in common fluid flows: (i) Surface-attached bacteria, biofilms and flow and (ii) Trapping of bubbles in stagnation point flows

4pm | Tuesday, May 16th 2017 | ESB 1001

Reception to Follow

Fluid mechanics is often thought of as well developed so it might come as a surprise that flows in elementary configurations produce results with unexpected features. I will try to make this case by describing several distinct problems that we have studied where either bacteria interact with a simple fluid motion in unexpected ways or modest variations in an elementary laminar channel flow produce new effects. First, we investigate some influences of fluid motion on surface-attached bacteria and biofilms. In particular, we identify (a) upstream migration of surface-attached bacteria in a flow, (b) a hydrodynamic reason for the shape of the curved bacteria Caulobacter crescentus, and (c) the formation of biofilm streamers, which are filaments of biofilm extended along the central region of a channel flow; these filaments are capable of causing catastrophic disruption and clogging of industrial, environmental and medical flow systems and suggest new flow problems influenced by soft boundaries. Second we consider flow in a T-junction, which is perhaps the most common element in many piping systems. The flows are laminar but have high Reynolds numbers, typically Re=100-1000. It seems obvious that any particles in the fluid that enter the T-junction will leave following the one of the two main flow channels. Nevertheless, we report experiments that document that bubbles and other low density objects can be trapped at the bifurcation. The trapping leads to the steady accumulation of bubbles that can form stable chain-like aggregates in the presence, for example, of surfactants, or give rise to a growth due to coalescence. Our three-dimensional numerical simulations rationalize the mechanism behind this phenomenon.

Some fluid mechanics vignettes: flow-driven bending, hydrodynamics of hot particles, and mixing-driven layering of colloidal solutions

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Light Refreshments

I present three fluid mechanics problems that we have studied recently, each of which identifies qualitatively new features inspired by classical flow problems. First, it is well known that the flow of thin liquid films has a large research literature in fluid mechanics. Also, the bending of an elastic beam has a large research literature in elasticity. Here we combine the two problems to study the spreading of a liquid over an elastic beam – the spreading fluid changes the shape of the beam and, in turn, the bending of the beam influences the fluid flow. Second, we consider the hydrodynamic resistance of a hot particle, as occurs when laser heating of a dilute suspension occurs. The viscosity varies with position about the particle which changes the familiar hydrodynamic drag. We present a solution using the Reciprocal Theorem so as to bypass many of the usual calculations and present situations that couple translation and rotation of a sphere. Finally, we show experiments and modeling to rationalize the formation of distinct layers when coffee (or an equivalent dyed solution) is poured into hot milk (a colloidal solution); a critical injection speed is shown to be responsible for the dynamics.