On air entrainment in a bath of liquid

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Abstract

A liquid or solid impacting a bath of liquid can, or not, entrain air with it (see the figure). This very familiar phenomenon (we all saw the foam resulting from cascades, or the bubbles which form when we fill a glass of water) is a classical question in the field of multiphase flows. People wonder in particular what is the condition of entrainment (as a function of the impact speed, for example), and what is the quantity of air which is injected in the bath (a critical question for the oxygenation of rivers, or for the formation of large-scale foams).

We try to answer these different questions in the particular case of viscous liquids impacting a bath of the same nature, such as it occurs when filling a cast with molten polymers or glass. We discuss the formation of singular zones in the region of impact, show how fragile they are, and propose simple arguments for understanding the flux of air injected in the bath, when entrainment occurs.

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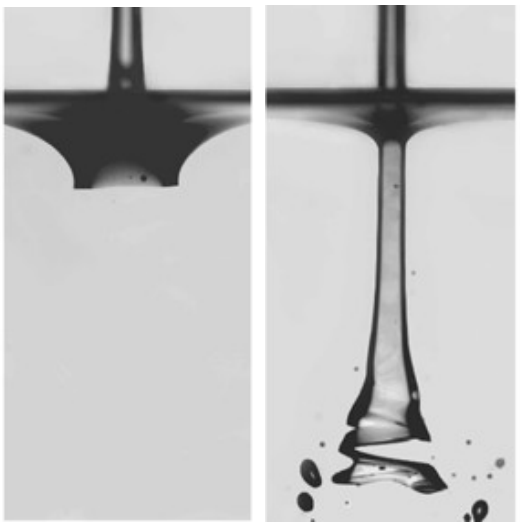

Figure 1: Jet of silicone oil 1000 more viscous than water hitting a bath of the same oil. The scale of both photographs is the same, with a jet diameter of 4 mm. On the left, the impact velocity is too small for observing air entrainment, yet large enough to dig a large hole at the bath surface. Note also the thickening of the jet as it makes this hole. On the right, we are above the threshold velocity of air entrainment, and the jet penetrates the bath coated with a sheet of air. The jet diameter increases as the jet gets deeper (and thus slower), and the film decays into bubbles after a few centimetres. You can notice the smaller meniscus at the bath surface (along the jet), when air entrainment is present.