A free boundary problem arising in the analysis of pressure swirl atomizers

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Pressure swirl atomizers are used to inject liquid fuels in combustion chambers, in the form of a hollow, conical, high velocity liquid film, so that it penetrates deeply while disintegrating into small droplets. The atomizers have an axisymmetric chamber where the liquid is fed, away from the axis, with an azimuthal circulating velocity; the swirling liquid flows out of the injector chamber through a cylindrical orifice of radius R_I and length L_I, small compared with those of the chamber.

It is possible to show that the axisymmetric flow can be described using an irrotational solution of the inviscid, Euler, equations, with a velocity field derived from a potential that satisfies the Laplace equation. The axisymmetric liquid domain is hollow inside and also outside the injector chamber, limited by two free boundaries that separate the liquid from the gas of the combustion chamber, of negligible density compared with that of the liquid.

We formulate the problem of determining, in terms of the volumetric flow rate and the circulating velocity, the two free boundaries of the liquid fuel, and the main characteristics of the solution, which are given explicitely for moderately large values of the ratio $\dfrac{\mathrm{L}_I}{\mathrm{R}_I}$.

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