Viscous effects on flows through pressure-swirl atomizers

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Abstract

Pressure-swirl atomizers are widely used in various industrial applications for their reliability in operation, and for the high liquid throughput paired with fine drop size of the sprays. Pressure-swirl atomizers are the standard atomizers in many spray-drying processes in, e.g., the chemical and food industries. An essential part of this kind of atomizers is the formation of a swirl which forces the process liquid into a rotating motion. The swirl may be imposed by an insert in the axial feed line inside the atomizer, or by tangential feed of the liquid into a swirl chamber. In both cases the liquid leaves the atomizer through a fine orifice in the form of an annular liquid sheet, which diverges in the flow direction and, therefore, assumes a conical shape with the thickness decreasing as the distance from the orifice increases.

The liquid flow rate through the atomizer depends, of course, on the driving pressure difference across the atomizer, the relevant geometric properties of the atomizer, and the liquid properties density and dynamic viscosity. One marked characteristic of the flow through pressure-swirl atomizers, which is yet unexplained, is the fact that, for a given atomizer geometry and at a given driving pressure difference, below a certain threshold liquid viscosity, the throughput of a liquid with a higher viscosity turns out higher than for a less viscous fluid. This behaviour of viscous liquid flows through swirl chambers, which is counter-intuitive at the first glance, is the subject of the present investigation.

We describe theoretically the flow through the swirl chamber, decomposing the flow field into three zones: (1) one radial outer zone at large distances from the axis of symmetry of the flow field, close to the swirl chamber wall, (2) one zone closer to the axis of symmetry, inside the radial extension of the inlet slits, and (3) the zone bounded by the gas-liquid interface at the air core. We model empirically the pressure drop across zones (1) and (2) and solve the transport equations for mass and momentum under simplifications appropriate for zone (3). The simplifications base on the negligibility of the axial velocity component in this zone. With the boundary and coupling conditions we arrive at a theoretical description of the flow field in the third zone, which allows us to relate the flow rate to the driving pressure difference for varying liquid properties and atomizer geometries. This modelling approach follows the lines of [1].

Results from the calculations quantify, among others, the liquid throughput and the air core radius. The data yield the trend observed experimentally: at moderate liquid viscosities, a liquid with a higher viscosity leads to a narrower air core, i.e., to a thicker wall-bounded film in the orifice, and, consequently, to a higher throughput than a less viscous fluid. The contribution to the conference will present the theoretical derivation in detail and present computational results in comparison with data from experiments, explaining the observed effect.

References

[1] Khavkin, Y., Strelkov, B. D., Nekhamkin, Y. E., *Teploenergetika* 10: 49-52 (1978).

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