Near Optimal Flows in a Swirl Atomizer

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Abstract

Here we offer a new inviscid theory of swirl atomizers. It is mathematically demonstrated that for a given reservoir pressure, a maximum possible discharge rate may be achieved only when the air core radius at the outlet happens to be the critical radius predicted by the theory. At the critical radius, the swirl atomizer is operated at an ideal condition and the pressure required is the minimum possible for a given discharge rate. In practice, a swirl atomizer is never operating at an ideal condition. This is due to many factors including the neglected viscous dissipation. Even for inviscid fluids the operation may not be optimal, either because the nozzle is too short or too long. For the former case the liquid layer has not yet thinned to the critical thickness. For the latter case the liquid layer is thinned beyond the critical thickness. An efficiency coefficient is defined to characterize the off optimal condition. Based on inviscid theory a third order algebraic equation is derived for the air core radius. A closed form solution of this equation is obtained. Based on this solution, the air core radius and the spray angle are calculated as functions of the efficiency coefficient and geometric parameters. These include the swirl chamber radius and the inlet radius (in the unit of the outlet radius). The theoretical results are compared with the known experimental results and some results of numerical simulation. The comparisons reveal the extent of the deviation of the experimental swirl nozzle from the ideal atomizer. With these comparisons, we are able to deduce the effects of various factors on nozzle efficiency. The present theoretical results may be used as a target for design improvement, and as a bound for numerical simulation of swirl atomizers.

Key words: modeling, sprays (diesel, medical, agricultural)

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