Cavitation Flow in Nozzle of Liquid Injector

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Abstract

It has been known that cavitation takes place in a nozzle of fuel injectors for internal combustion engines and strongly affects the characteristics of discharged fuel spray. Hence, a large effort has been paid to understand cavitation flow in single nozzles with a symmetric inflow. Cavitation in a nozzle is affected by liquid velocity, geometry of the injector, needle lift, length-to-diameter ratio of the nozzle, curvature of the inlet edge, liquid property, dissolved gases in a liquid, system pressure, and so on. In this study, cavitation flow in various nozzles of 4 mm in width W with an asymmetric inflow, different needle lifts Z (Z/W = 1, 2 and 4), nozzle angles θ (θ = -30, -20, 0, 20, 30 deg.) and various water temperatures T_L (T_L = 285, 305, 326 K) are visualized to clarify the effects of an asymmetric inflow, needle lift, nozzle angle, and fluid property on cavitation flow in a nozzle of liquid injectors.

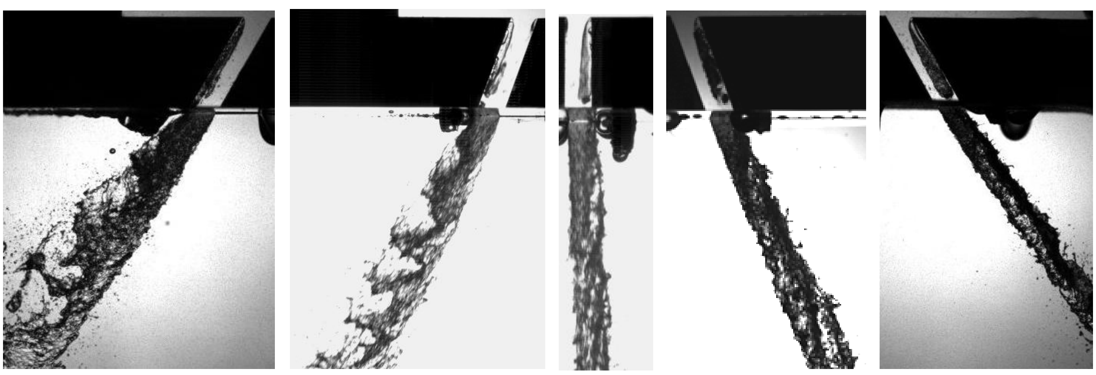
Various two-dimensional (2D) nozzles are manufactured and used to measure the length and thickness of cavitation appearing in the nozzles. Transient behavior of cavitation in the nozzles and the deforming liquid jets are visualized using a high-speed cameras and a metal-halide lamp. The ratio of the length L and the width W of the nozzles are 4.

Figure 1 shows the images of cavitation in tilted nozzles with various nozzle angles θ. Due to the asymmetric inflow mainly from upstream right into the nozzle, a thick separated boundary layer and cavitation appears and grows asymmetrically mainly along the right wall even for θ = 0 degree. The asymmetric and thick cavitation induces an asymmetric and large-scaled deformation of the discharged liquid jet. We also found that the decrease in needle lift Z results in a thicker and longer cavitation as well as a larger deformation of the liquid jet. An acute angle of the nozzle inlet edge is found to enhance the cavitation thickness and its development as well as a large deformation of the discharged liquid jet.

Through the investigation of cavitation flow with different water temperature T_L, we confirmed that cavitation does not depend on the Reynolds number Re in the range of Re > 12500 but strongly on the modified cavitation number σ_C, which is based on local pressure at vena contracta.

Finally, we found that cavitation taking place in a nozzle of liquid injectors is strongly affected by the profile of the separated boundary layer, which depends not on the Reynolds number Re but strongly on an asymmetric inflow, needle lift Z and nozzle angle θ.

These results suggest that by knowing the contraction coefficient C_C we can quantitatively estimate the inception and development of separation-induced-cavitation even for various injector geometries, needle lifts, and fluid properties.



(a) θ = 30 deg (b) θ = 20 deg. (c) θ = 0 deg. (d) θ = -20 deg. (e) θ = -30 deg.

Figure 1 Cavitation in tilted nozzles with various nozzle angles θ and liquid jets (Z/W = 4, W = 4mm).

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