Study of the influence of internal flow on the spray behavior under cavitating conditions using a transparent nozzle

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Abstract

One of the areas of interest in diesel engines is the study of nozzle flow behavior in fuel injectors. As it is well known through previous studies the flow behavior inside the orifice is strongly related to the behavior of the spray at the exit and its interaction with the air, affecting the mixing and combustion process.

In the present work, behavior of the internal flow under cavitating conditions and its influence on the spray behavior is studied. For this purpose, a transparent nozzle plate with a cylindrical orifice is used. The transparent nozzle, made of fused silica SiO2, has an exit diameter of 0.51mm and 1mm length and it is installed in a pressurized rig with fuel (commercial diesel) in order to measure the mass flow and observe the flow inside the orifice, as well as the spray at the exit, using a special visualization technique. The rig consists of a stainless steel vessel, including two opposed optical windows to perform backlighting visualization.

The optical system developed for visualization includes light source with optical fibers, a PCO SensiCam CCD camera and one optical lens, aligned between each other in order to reach high zoom levels. Additionally, an optical diffuser is placed after the light flash exit. This element diffuses the flash light and produces a uniform illumination in the chamber region under study. All images are obtained at a resolution of 1280X1024 pixels and 3mm of window size.

During the initial phase of the work, the hydraulic characterization of the nozzle is done by measuring the mass flow of the nozzle injecting fuel at stationary conditions. For this purpose, the test rig is filled with fuel and the nozzle injects in continuous flow and measuring the mass that escapes the test rig (with a gravimetric balance) for a given time, the stationary mass flow can be calculated. Mass flow is measured for different conditions of injection and discharge pressures. Simultaneously, the visualization of the orifice is carried out in order to observe the cavitation inside the orifice and the bubbles in the spray.

Additional measurements are carried out in the rig pressurizing with nitrogen to observe the spray at the outlet orifice using the same measurement conditions and the same visualization technique. This configuration allows determining the correspondence between the behavior of the flow inside the orifice and the spray at the exit.

The results from the hydraulic characterization show that the beginning of the cavitation (incipient cavitation) occurs before the mass flow collapse. Furthermore, the presence of bubbles in the spray before the mass choke indicates the existence of cavitation.

Finally, the images obtained with the rig pressurized with fuel and with nitrogen are compared to observe the influence of cavitating flow inside the orifice on the development of the spray. It is observed that the spray experiences a significant change in the cone angle once the cavitation is fully developed through the whole orifice.

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