Abstract

The growing public aversion to internal combustion engines has led to a strong desire to shift towards renewable and cleaner energy sources. However, it is still hard to replace petroleum-derived liquid fuels as the primary energy source, mainly due to their plenty of availability, reliability, and affordability. Then, efforts have to come from the research community to increase the efficiency of these engines for the benefit of society.

Regarding diesel engines, one implemented technique has been to increase the number of outlet holes of the injector and reduce their diameters, enhancing the air/fuel mixing process. Nevertheless, as the number of holes in the nozzle increases, so does the proximity between them, leading to a reduction in the space available for each jet to develop without interacting with the neighbor sprays. This interaction could affect the combustion event, and its implications have not been entirely defined.

Thus, the present thesis aimed to analyze the influence of inter-jet spacing on the injection development and enhance the methodology employed in the institute to study injection events of multi-holes injectors, accounting for the interactions between jets.

To this end, two diesel injectors with six outlet orifices were manufactured by Continental with identical design, except for the geometric distribution of the outlet holes of each nozzle, as they were specifically allocated to study the influence of inter-jet spacing on the injection event. Concretely, the first injector allowed the study of the development of an isolated spray on one side and a spray with an inter-jet spacing of 30° on the other side during the same injection event. Moreover, the second injector has two additional orifices distributions, so a total of three inter-jet spacing configurations (30° - 36° - 45°) were compared to the performance of the isolated spray (spacing = 120°). Additionally, a novel optical window and high-temperature ceramic mirror were successfully tested.

The results were grouped into analyses under non-reactive and reactive environments. The experiments under a non-reactive environment were mainly done to assess the similarity or variance in performance due to fabrication differences between the injectors, finding that the inter-jet spacing did not affect the injection event under non-reactive conditions.

Then, the studies focused on the injection event under a reactive environment, analyzing the influence of inter-jet spacing on the ignition delay, lift-off length, and soot formation.

Regarding the ignition delay, sprays with neighbor jets tended to have

equal or slightly smaller ignition delay values under poor mixing and ignition conditions (low rail pressure, chamber temperature, or chamber density conditions). On the other hand, the opposite effect was generally observed as the boundary conditions were overall increased, with equal or higher ignition delay values within sprays with neighbor jets, compared to that of the isolated spray. Nonetheless, no clear trend was defined, with complex interactions and multiple factors simultaneously affecting the ignition event.

On the lift-off length, the results showed that after certain proximity between sprays is reached, the interaction between the jets becomes a predominant factor in their behavior, and the lift-off length is considerably reduced. Moreover, as the inter-jet spacing increases, the performance gradually approaches that obtained from the isolated spray. Plausibly, closely spaced sprays entrain a higher amount of hot combustion products and radicals. Then, the entrained gas with a higher temperature could trigger autoignition near the nozzle, reducing the lift-off length. Lastly, a novel regression for the lift-off length was developed, which accounted for the effect of the proximity between sprays.

Respecting the soot formation, the sprays with closely spaced neighbor jets (30° and 36°) generally had higher optical thickness KL and peak soot mass values for a given boundary condition when compared to the development of the isolated spray. These trends are in line with the lift-off length results observed, in which the closely spaced jets had a shorter lift-off length due to (plausibly) hot gases re-entrainment. This shortening would deteriorate the air/fuel mixing process and, consequently, combustion happens in richer mixture conditions that are suitable for soot formation. On the other hand, the impact of the inter-jet spacing was smaller as the boundary conditions promoting soot formation were enhanced, that is, increasing the ambient density, ambient temperature, or reducing the rail pressure.

Additionally, the influence of the chamber temperature, chamber density, and rail pressure on the spray behavior was assessed. The observed impact of these parameters on the spray followed the trends found in the literature and served to validate the consistency of the work done.