An investigation of the effect of close injections under low levels of CO_2 dilution on a single cylinder optical Diesel engine

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Diesel engines performance optimization is essential in order to meet emissions regulations. Control schemes based on selection of multiple injection strategies and increased exhaust gas recirculation can lead to a modification of conventional diesel combustion, potentially exhibiting characteristics of partially premixed combustion mode. Conventional diesel combustion is predominantly governed by fuel-air mixing as well as their reaction rates, or in other words, by both mixing- and kinetically- controlled phases. Novel combustion modes diverge from conventional flames and shift towards kinetically-controlled combustion schemes, such as partially-premixed, essentially moderating the diffusion phase, which is largely responsible for soot and NO_x formation. The latter may be brought about by early injections, leading to long ignition delays, short combustion durations and rapid heat release rates. Multiple injection strategies introduce a sequence of events which, depending on the injection schedule, could even transform diesel combustion into a series of low temperature premixed combustion events. Enhanced premixing lowers smoke levels due to either a shorter formation period as compared to conventional combustion, or by generally avoiding soot formation valleys on the Φ-T space. The present work investigates the effect of low level CO_2 addition on the combustion characteristics inside a single cylinder optical engine operated under low load and low speed. The effects of dilution levels, the number of pilot injections and injection, are evaluated towards the direction of achieving partially premixed combustion. Measurements performed in a Ricardo Hydra optical light duty diesel engine, operated under low IMEP levels of the order of ca.2 bar at 1200 rpm. Spray behavior and flame propagation is captured by means of high speed imaging and OH, CH and C_2 line of sight chemiluminescence respectively. Each of the above species is a proxy of a fundamental combustion property; OH^* is related to the oxidation zone, CH^* to the heat release zone and the flame front, while $C2^*$ is indicative of fuel-rich areas. The analyses of the obtained results were made under the perspective of identifying the induced alterations in flame structures and, possibly, combustion modes, and their manifestation at the global in-cylinder thermodynamic conditions. The increase of CO_2 addition results in lower peak pressures and in an overall delay of the combustion process, while also influences the spatial characteristics of reaction and oxidation zones, as well as differentiates the extent of fuel-rich pockets. Multiple injections advance the main combustion event and an increase in injection pressure enhances fuel evaporation and mixing while spatially confining the observed flame structures. Overall, operation under relatively slightly diluted conditions with more pilot injection events at higher rail pressure appear to enhance mixing, proving thus an indication of lower emission levels.