Investigation of Particulate Emissions for Cluster-Nozzle Concepts in DI Diesel Engines

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Abstract

In a conventional Diesel engine, air is gradually drawn into the fuel spray from the surrounding area. The ignition delay period is short, so combustion starts before the fuel has thoroughly mixed with the air. Consequently, the center of the spray is overly rich, resulting in smoke, while stoichiometric mixture is formed in the surrounding area, resulting in a high NOx concentration. Based on the Diesel concept, it is practically impossible to totally avoid fuel-rich and stoichiometric pockets, but the formation of soot and NOx are also time-dependent. If the mixing time is sufficiently small, both pollutants could be reduced simultaneously without getting into the well known soot-NOx tradeoff. In order to develop a low-emission engine, research is necessary to come up with a new combustion strategy for Diesel engines which includes the use of cluster nozzles. Decreasing the hole-size improves mixing in the center of the spray and therefore the soot production is lowered tremendously. Based on this experience, three cluster designs were developed for the present work. The basic strategy of the cluster nozzles is to provide a better primary breakup and therefore a better mixture formation caused by the smaller nozzle holes, while keeping a comparable penetration length of the vapor phase due to merging of the sprays. In this study, two different cluster-nozzle designs were investigated in a combustion vessel and compared to a conventional nozzle with the same flow rate. Two different measurement techniques are employed to investigate the combustion process. The local soot concentration during combustion is measured semi-quantitatively using Laser Induced Incandescence (LII). The natural soot luminosity is recorded simultaneously using a double frame camera. The results indicate that soot formation can be reduced by using cluster nozzles, at least in the early combustion phase under the investigated conditions. Three cluster designs similar to the ones used in the combustion vessel, were investigated through engine measurements. The nozzles used in this study were designed for improved homogenization of in-cylinder charge. They were tested in a single-cylinder engine with CRI 3.3 piezo-injectors under part-load conditions for a partly homogenous mode of Diesel combustion, and also under high load conditions for conventional Diesel combustion. Numerical simulations were also carried out to explain the observations of the engine experiments. Certain test cases were simulated to get some detailed information on performance of cluster nozzles, giving more insight into soot formation. Another nozzle was designed based on the results from the three clusters. Engine experiments with the nozzle show improvements in soot emissions under high-load conditions.

Key words: Cluster-Nozzles, Soot, PCCI, LII, DI Diesel Engine

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