A MIXED-MODE HCCI/DI ENGINE BASED ON A NOVEL DIESEL FUEL ATOMIZER

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The homogeneous charge compression ignition (HCCI) mode has long been touted as the next engine combustion system to combine the high efficiency of diesel engines with very low tail-pipe emissions; however, it has been demonstrated only in the laboratory under very controlled conditions. It is clear that achieving a robust and controllable HCCI combustion system capable of handling heavy fuels in engines under a realistic and wide range of operating conditions and transients is not feasible today.

Our approach is aimed at developing a compression engine capable of operating with heavy fuels over a wide range of operating (speed, load, temperatures) conditions in a robust and controllable fashion to achieve both high thermal efficiency and low emissions. Furthermore, our approach builds upon the technological recent advances and successes in advanced CIDI engines, married with a novel enabling technology in ultra-fine heavy fuel atomization and advances in modern, model-based engine control systems.

The novel atomizer is a low-pressure system capable of atomizing heavy liquid fuels in a "fog-like" suspension of sub-micron liquid droplets over a very wide range of temperature conditions. The air/fuel mixture so formed has many positive attributes: it behaves in a gas-like manner; is highly resistant to settling and segregation, subsequent film condensation, and wall wetting; and is highly homogeneous and capable of achieving a well-mixed air/fuel vapor mixture very fast due to the extremely high surface-to-volume ratio of the fuel droplets.

Our engine concept is also a mixed-mode, HCCI/CIDI combustion system:
part of the fuel is introduced in the engine to achieve a lean and very homogeneous, premixed phase capable of combusting in an HCCI mode, while part of the fuel is introduced directly by a common rail direct injection (DI) system. The non-condensing, highly mixed nature of the fuel/oxidizer mixture achieved with the novel atomizer enables port injection for the preparation of a very lean and highly homogeneous phase capable of supporting the HCCI combustion mode at low-to-medium loads. The CR-CIDI conventional injection system enables the medium-to-high load operation, which is not feasible with a pure HCCI combustion system. However, both systems are intended to operate *simultaneously* with the emphasis between the two systems shifting as load/speed varies. We foresee that the DI injection at high loads into a lean and homogenous air/oxidizer mixture phase will further extend the PM/NO_x trade-offs and limits facing conventional CIDI engines. At low-to-medium loads, a relatively smaller DI part can act as a "combustion" trigger for the otherwise homogeneous (and possibly lean) phase, hence capable of achieving much greater controllability of the combustion system. This mixed-mode fueling strategy is combined with advanced, model-based control for the VGT/EGR loop to achieve at each cycle a reliable estimate and control of

the thermochemical oxidizer charge, hence achieving the narrow range of intake conditions required for proper HCCI operation.

Finally, the system is to be used with an active, thermochemically managed exhaust aftertreatment system. Again, the novel atomizer plays a significant enabling role to achieve the thermochemical management of a bifurcated lean-NO_x trap system, which does not require an engine-based reductant addition to achieve NO_x trap regeneration.