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A New Combustion System Achieving High Drive Cycle Fuel Economy Improvements in a Modern Vehicle Powertrain

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ABSTRACT

Turbulent Jet Ignition is an advanced spark initiated pre-chamber combustion system for otherwise standard spark ignition engines found in current passenger vehicles. This next generation pre-chamber design simply replaces the spark plug in a conventional spark ignition engine. Turbulent Jet Ignition enables very fast burn rates due to the ignition system producing multiple, widely distributed ignition sites, which consume the main charge rapidly. This high energy ignition results from the partially combusted (reacting) pre-chamber products initiating combustion in the main chamber. The distributed ignition sites enable relatively small flame travel distances enabling short combustion durations and high burn rates. Multiple benefits include extending the knock limit and initiating combustion in very dilute mixtures (excess air and or EGR), with dilution levels being comparable to other low temperature combustion technologies (HCCI), without the complex control drawbacks.

Previous Turbulent Jet Ignition experimental results have highlighted peak net indicated thermal efficiency values of 42% in a standard contemporary PFI engine platform. Additionally, the pre-chamber combustion system is capable of tolerating up to 54% mass fraction diluent (combination of excess air and EGR) at the world wide mapping point, resulting in near zero engine out NOx emissions. The purpose of this paper is to conduct a more thorough analysis of the technology and highlight the current speed load envelop recently achieved. Mini-map speed load experimental data is presented in this paper and used to generate several simulated drive cycles in a medium class passenger vehicle. Drive cycle fuel economy comparisons are then made across combustion regimes in the same engine platform, including stoichiometric spark ignition, lean burn spark ignition, HCCI and Turbulent Jet Ignition. Analysis highlights that a drive cycle fuel consumption improvement near 25% can be achieved with the Turbulent Jet Ignition combustion system, albeit with the high potential in meeting current day and future legislative emission regulations without the need for expensive lean NOx after-treatment. This would exceed the drive cycle fuel economy improvement achieved with other low temperature combustion technologies (HCCI) in the same engine platform as there is no requirement to switch back to conventional spark ignition combustion at high and low loads, which limits fuel economy improvements and maximum compression ratio for knock avoidance.