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A Normally Aspirated Spark Initiated Combustion System Capable of High Load, High Efficiency and Near Zero NOx Emissions in a Modern Vehicle Powertrain

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ABSTRACT

Turbulent Jet Ignition is an advanced spark initiated pre-chamber combustion system for an otherwise standard spark ignition engine found in current on-road 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 system results from the partially combusted (reacting) pre-chamber products initiating main chamber combustion. The fast burn rates allow for increased levels of dilution (lean burn and/or EGR) when compared to conventional spark ignition combustion, with dilution levels being comparable to other low temperature combustion technologies (HCCI) without the complex control drawbacks.

Previous Turbulent Jet Ignition light load results at the world wide mapping point (1500 rev/min, 3.3 bar IMEPn) have demonstrated an 18% improvement in fuel economy, with single digit ppm engine out NOx emissions. This paper focuses on performance, efficiency, emissions and combustion effects of a Turbulent Jet Ignition system operated at unthrottled conditions with load variation achieved by altering the dilution level (excess air and/or EGR).

Turbulent Jet Ignition single cylinder experimental results at 1500 rev/min highlight a matched load operating range when compared to conventional spark ignition combustion, with identical peak BMEP and the ability to operate in an unthrottled mode down to 3.9 bar IMEPn with increasing dilution levels.

The high diluent fraction and resultant low temperature combustion has resulted in a peak indicated net thermal efficiency of 42% to be recorded together with near zero engine out NOx emissions. This was achieved utilizing the engine's standard PFI fuel delivery system and a relatively low compression ratio of 10.4. Efficiency gains are attributed to a combination of combustion improvements, reduced heat losses and the near elimination of dissociation associated with low combustion temperatures. Peak efficiency improvements equate to an 11% relative improvement when compared to conventional stoichiometric spark ignition combustion. Results also indicate that jet ignition combustion has the potential to exceed 45% indicated net thermal efficiency (19% relative improvement) with a CR increase to □14. The CR increase is made possible by the burn rate improvement associated with the distributed ignition system and the addition of side, wall guided DI. This would exceed the HCCI peak thermal efficiency of 43% in the same engine platform as there is no requirement to switch back to conventional spark ignition combustion at high load operation, which limits HCCI maximum CR for knock avoidance.