2010-01-2260

Flame Kernel Development for a Spark Initiated Pre-Chamber Combustion System Capable of High Load, High Efficiency and Near Zero NOx Emissions

William P. Attard, Patrick Parsons
MAHLE Powertrain LLC

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 experimental results have highlighted peak net indicated thermal efficiency values of 42% in a standard modern engine platform. Additionally, the pre-chamber combustion system is capable of tolerating up to 54% mass fraction diluent (excess air and EGR) at the world wide mapping point of 1500 rev/min, 3.3 bar IMEPn (□2.62 bar BMEP), resulting in an 18% improvement in fuel economy and near zero engine out NOx emissions.

This paper focuses on single cylinder experiments at the world wide mapping point, which attempted to extend the dilution level further by altering the flame kernel development inside the very small but rich pre-chamber environment. Turbulent Jet Ignition experiments incorporated previous techniques found to affect the dilution limits in conventional spark ignition combustions systems. This included variations in spark plug type, orientation, location and electrode gap for the spark plug initiated pre-chamber combustion system. Experimental results highlighted that the pre-chamber combustion system is quite robust and largely unaffected by these changes, unlike conventional spark ignition combustion, as long as combustion inside the pre-chamber can be initiated. This occurs as combustion in the heavily diluted main chamber is driven by the chemical, thermal and turbulence effects of the propagating jet exiting the pre-chamber and not the flame front itself. Nevertheless, experiments found the eliminating the dead volume near the spark plug inside the pre-chamber, was beneficial in reducing the trapped residuals and thus enabled the dilution level to be slightly improved from an exhaust lambda of 2.08 to 2.14 (54 to 56% mass fraction diluent).