2012-01-1143

Knock Limit Extension with a Gasoline Fueled Pre-Chamber Jet Ignitor in a Modern Vehicle Powertrain

William P. Attard, Hugh Blaxill
MAHLE Powertrain LLC

Eric K. Anderson
National Research Council

Paul Litke
US Air Force Research Laboratory

ABSTRACT

Turbulent Jet Ignition is an advanced spark initiated pre-chamber combustion system for otherwise standard spark ignition engines. Combustion in the main chamber is initiated by jets of partially combusted (reacting) pre-chamber products which provide a high energy ignition source. The resultant widely distributed ignition sites allow relatively small flame travel distances enabling short combustion durations and high burn rates. Demonstrated benefits include ultra lean operation (λ>2) at part load and high load knock improvement.

This study compared the knock limit of conventional spark ignition and pre-chamber jet ignition combustion with reducing fuel quality in a modern PFI engine platform. Seven PRF blends ranging from 93-60 octane were experimentally tested in a stoichiometric normally aspirated single cylinder research engine at 1500 rev/min and ~WOT (98 kPa MAP). The majority of jet ignition experiments utilized an unfueled pre-chamber (no pre-chamber auxiliary fuel addition), with results highlighting significant knock limit extension with this combustion system. At MBT combustion phasing, a 10 octane number improvement was recorded with the unfueled pre-chamber over conventional spark ignition combustion due to the burn rate enhancement. At the combustion stability limit (3% CoV IMEPg) with spark retard, the unfueled pre-chamber jet igniter was capable of operating on 65 octane fuel, corresponding to a >15 octane number benefit due to the increased ignition delay and the ability to burn the main charge very late and very quickly. This is estimated to correspond to a base compression ratio increase of ~3 points over conventional spark ignition combustion at the 1500 rev/min test condition, in the same test engine. Additional experiments were also completed using an auxiliary fuelled pre-chamber, with the PRF fuel fed into the pre-chamber cavity as well as the PFI main chamber. Results highlight further burn rate enhancement when fueling the pre-chamber independently of the main chamber, with successful WOT engine operation utilizing 60 octane fuel. Further experiments using standard US 87 (R+M)/2 pump fuel were completed up to 5500 rev/min and 13 bar IMEPn, with similar knock limit extensions observed with the pre-chamber jet igniter when compared to the baseline spark ignition combustion system.